Cedar River Municipal Watershed Riparian Restoration Strategic Plan

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Executive Summary

Riparian restoration is a component of the watershed management mitigation and conservation strategies included in the Cedar River Municipal Watershed (CRMW) Habitat Conservation Plan (HCP) (City of Seattle, 2000). The CRMW-HCP identified two primary management activities to achieve riparian restoration goals: conifer underplanting and restoration and ecological thinning. In order to effectively implement riparian restoration in the CRMW, this Strategic Plan describes a process to identify riparian restoration needs and opportunities and to plan restoration activities. This document is linked to other strategic plans for CRMW restoration that discuss aquatic and upland restoration, watershed characterization, monitoring, and landscape-level prioritization. The plan explicitly incorporates an asset management approach to riparian restoration.

Strategic Framework for Riparian Ecosystem Conservation and Restoration

We believe that the general goal of the riparian component of restoration under the HCP is to:

Promote the restoration of ecological processes that create and maintain the natural range of variation in riparian functions and habitat, within the constraints of managing the CRMW as a municipal water supply.

We use an ecosystem-based definition of riparian areas that captures the ecological processes important for riparian restoration:

Riparian areas are three dimensional ecotones of interactions that include terrestrial and aquatic ecosystems that extend into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable width.

Physical and Biological Processes of Riparian Areas

As the interface, or ecotone, between terrestrial and aquatic environments, riparian areas are influenced by ecosystem processes occurring throughout the watershed. Physical processes include geomorphic processes controlling valley morphology, mass wasting, debris flows, floods, and channel migration. Biological processes include forest succession, competition, and herbivory. In riparian areas, physical disturbance from the river environment results in open substrate that is colonized by plants and undergoes succession to later seral stages. Succession on floodplains can have any of several trajectories, which appear to be strongly controlled by soil moisture levels. Higher soil moisture levels often lead to dominance by deciduous and shrub species, inhibiting conifer regeneration. Restoration actions in forested riparian areas are often directed at increasing conifer growth and abundance in early seral stages.

Characterization of Historical and Current Riparian Characteristics

We have classified CRMW riparian areas into seven types based on stand age and dominance by conifer or deciduous tree species, shrubs, or herbs. Riparian areas have been mapped into these different classes using remote sensing data, and the classes serve to identify areas where restoration actions are most likely needed.

Historical conditions of riparian areas are being characterized to provide a benchmark for restoration and to better understand the effects of disturbance caused by timber harvest and road building. In general, most pre-settlement riparian forests in the CRMW were conifer-dominated, although there were likely patches of deciduous or mixed conifer-deciduous dominated forest, primarily along lower gradient streams with broader floodplains. Disturbance effects included removal of mature conifer forest, debris flows, and destabilized channels and floodplains, which have resulted in lower large woody debris recruitment and shade, higher rates of channel migration, and changes in hydrology to wetland habitats.

The "Measures of Success" Framework for Riparian Restoration

SPU's Watershed Ecosystems section has incorporated a framework for ecosystem restoration developed by The Nature Conservancy, sometimes referred to as the "Measures of Success" framework (Parrish *et al.*, 2003). As modified for riparian restoration in the CRMW, major steps in this approach include:

1. **Identify restoration targets,** which refer to a set of riparian areas that differ from one another in functional level, restoration need, and dominant physical and biotic processes. We have identified six restoration targets based on cover type and geomorphic setting.
2. **Identify key ecological attributes for each restoration target.** We use ecological functions as the attributes for characterizing the present condition and evaluating success of restoration efforts. Key riparian forest ecological functions include: LWD recruitment, stream shading, maintenance of bank stability, providing structural complexity to wildlife, and providing forage for beaver. Indicators are identified for each attribute.
3. **Develop a conceptual model for each restoration target.** Conceptual models are developed for explicitly laying out the assumptions and hypotheses that underlie our understanding of how restoration might alter a particular restoration target. The models relate current conditions to disturbance history, site characteristics, and vegetation and watershed processes and show how future conditions are potentially affected by natural processes and restoration actions to result in future levels of key functions.
4. **Define acceptable range of variation for future conditions.** Desired future conditions (DFCs) provide criteria for evaluating the need for and the success of restoration actions. DFCs need to be developed for each key ecological function with associated indicators specific to each restoration target. We have acquired substantial data to quantify DFCs for various indicators, however there are still some data gaps.
5. **Assess the current status of restoration targets.** Assessing the current conditions of key indicators allows us to see how they compare to the acceptable range of variability along riparian forest successional trajectories. We have identified eight critical knowledge gaps to fill in order to adequately quantify the indicators for key ecological attributes (i.e., functions) in riparian areas.
6. **Identify strategies for achieving desired future conditions.** Because the watershed under the HCP is effectively an ecological reserve, natural recovery, or passive restoration, is the default for the 50 year HCP period. In addition, active restoration includes several possible treatments to apply where we believe intervention is needed and cost effective. These include restoration and ecological thinning, conifer underplanting

preceded by appropriate understory or overstory clearing, and conifer release (i.e., thinning around existing young conifers).

7. **Assess the success of strategies to achieve desired future conditions.** Evaluation of restoration interventions is critical to reducing uncertainty in their effectiveness and determining if our efforts are achieving the intended results. We intend to conduct the CRMW riparian restoration program within an adaptive management framework to learn from early restoration projects and use these results to reduce uncertainty and improve the effectiveness of riparian restoration interventions.

Prioritizing Riparian Restoration Projects

Prioritizing riparian sites for restoration treatment is being done at two levels. At a watershed scale, a "landscape synthesis" process has identified areas where application and synergy of restoration efforts in aquatic, riparian, and terrestrial ecosystems can best occur to produce the greatest ecological benefit. These will be priority areas for potential restoration treatment among all restoration programs in terms of overall landscape position. At the reach scale within these "synergy areas", this riparian strategic plan addresses how reaches will be prioritized for riparian restoration.

The "synergy areas" were identified as areas having high combined value from four themes representing different aspects of watershed biodiversity:

- Fish – which includes the distribution of anadromous salmon and bull trout within the watershed;
- Forest connectivity – which shows areas where existing late seral – old growth or high quality second growth forests occur and where the most effective areas for reconnecting occur;
- Amphibian habitat – includes complexes of aquatic, riparian, and upland areas most likely to be important for amphibians in the watershed; and
- Areas adjacent to biodiversity hotspots – which include areas that either have high species diversity or contribute to overall diversity, such as rock, meadows and shrub lands, depressional wetlands, and old growth forest.

Four basic criteria have been identified for prioritizing riparian restoration sites within the "synergy areas", including:

- Current and expected level of key functions relative to desired future conditions,
- Importance of a particular key function within a reach,
- Presence of species of concern, and
- Potential response to restoration actions.

As this work is required under the incidental take permit (HCP), the approach is to identify the most effective and highest priority projects for the cost commitment level (i.e., biggest bang for a given level of dollars). After prioritizing projects and /or sites for riparian restoration, an estimation of costs can be done to select among the higher priority projects/sites for detailed planning and implementation. Weighing estimated costs against priority ranking is a semi-quantitative way to evaluate costs vs. benefits. This process should ensure that our restoration funding goes to those projects and locations where the most benefit can be achieved for a reasonable cost.

A near-term list of riparian restoration projects is being developed based on the prioritization process currently in progress. When this list is completed, it will be added to the strategic plan, and it will be updated annually as projects are implemented or newly identified/prioritized.

Planning and Implementing Riparian Restoration Projects

We describe standards and guidelines for developing project plans and implementing those plans. Project plans will include or consider: a site description; project description, objectives, and justification; coordination with other projects; evaluation of potential project effects; any needed project mitigation; evaluation of cost versus benefits; need for outside review, permitting, and approvals; contract development; and an adaptive management and monitoring plan.

For larger projects, an Implementation Plan may be useful as a stand-alone document and included as Appendix A to the project plan. Implementation Plans are to be written for use in the field by personnel conducting the project and would include specifications for baseline monitoring, identification of needed resources, mobilization and safety requirements, coordination with other projects, project design specifications, and mitigation measures.

Next Steps

There are several items in this strategic plan that are not yet completed for the plan to be considered finished. Rather than wait until all these pieces are complete, we are publishing this draft of the plan, with the idea that it will be updated as remaining tasks are completed. These next steps include:

- Data acquisition and assessment of current and desired future conditions
- Setting triggers for long-term adaptive management
- Project prioritization and development of near-term project list

Role of the Riparian Restoration ID Team

Upon completion of the Strategic Plan, the Riparian Restoration ID Team will continue to function as a group to prioritize, plan, and coordinate riparian restoration projects and monitoring. The interdisciplinary composition of the ID team provides a good forum for discussing and evaluating project proposals and coordinating projects with other restoration ID teams.

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Cedar River Municipal Watershed Riparian Restoration Strategic Plan

1. Introduction and Background

Riparian restoration is a component of the watershed management mitigation and conservation strategies included in the Cedar River Municipal Watershed (CRMW) Habitat Conservation Plan (HCP) (City of Seattle, 2000). The CRMW HCP was developed to protect and restore habitat for species listed under the federal Endangered Species Act and other species of concern, while allowing the City to continue providing high quality drinking water and electrical power to the region from the CRMW.

Riparian areas are "ecotones" linking terrestrial and aquatic ecosystems. They provide numerous functions important to maintaining the ecological integrity of aquatic ecosystems, such as shade to maintain lower water temperatures, nutrient cycling, minimizing sediment input from upland activities, and recruitment of large woody debris to the stream channel (Berg *et al.*, 2002). In addition to their critical role in aquatic ecosystem function, riparian areas provide unique habitat features important to terrestrial species as a result of their structural diversity, species composition, and proximity to water (Gregory *et al.*, 1991).

Restoring riparian areas is an emerging science, especially with regard to coniferous forests west of the Cascade Mountains. In addition, we have a limited understanding of ecological processes within aquatic-riparian ecosystems. Acknowledging and addressing the uncertainties involved in restoring riparian ecosystems, this document serves to establish a rationale and strategic approach to identify and prioritize riparian areas where management actions will most effectively contribute to meeting HCP goals and objectives. It further recommends planning, implementation, and monitoring processes for achieving riparian restoration objectives in the CRMW.

1.1. Purpose of this Document

This Strategic Plan describes a process to identify riparian restoration needs and opportunities and to plan restoration activities. The plan is intended to provide a comprehensive, science-based approach to riparian restoration, maximizing benefits from individual reach-scale actions to ultimately achieve sub-basin and watershed restoration. It provides a framework for making scientifically sound decisions in coordination with other HCP activities about where and how to implement riparian restoration within the CRMW. The plan has the following objectives:

- Provide a strategic framework for conserving and restoring riparian ecosystems in the CRMW;
- Describe a process for prioritizing riparian restoration in the CRMW;
- Provide a set of standards and guidelines for planning and implementing riparian restoration in the CRMW

We expect this strategic plan to be a "living document" that will be updated as information becomes available to inform the plan and as we learn from planning and implementing restoration projects. The plan should be a guide to strategically identifying, planning, and implementing riparian restoration within a broader "synthesis" approach to watershed restoration that includes upland and aquatic restoration.

1.2. HCP Goals and Objectives for Riparian Areas

Under the HCP, the City of Seattle is committed to:

…conservation measures to enhance and restore stream habitats, increasing the structural complexity of riparian and instream habitat, by accelerating the reestablishment of diverse and structurally complex riparian forests and associated ecological functions (CRMW HCP pp. 4.2-58).

The CRMW-HCP identified two primary management activities to achieve riparian restoration goals:

- *Conifer underplanting*: to reestablish conifers in riparian and streamside areas in order to accelerate the restoration of diverse and structurally complex riparian stands within the watershed (CRMW HCP pp. 4.2-59).
- *Restoration and ecological thinning*: to accelerate the growth and structural development of trees in riparian stands, providing eventual reestablishment of older riparian stands with high structural and habitat diversity to help restore natural stream and riparian ecosystem functions (CRMW HCP pp. 4.2-61).

1.3. Linkages to Other Plans and Documents

There are other guiding documents for watershed restoration in the CRMW to which this strategic riparian restoration plan is intimately linked. Figure 1 shows the hierarchical relationship of these various plans and documents.

In addition to this strategic riparian restoration plan, there are strategic upland and aquatic restoration plans. These plans provide similar frameworks for restoration within their respective ecosystems and describe how restoration is to be prioritized, planned, and implemented. A fourth plan, the *Transportation Strategic Asset Management Plan* (TSAMP), addresses how management and decommissioning of roads within the CRMW will be carried out (_________ 2006). By working together in developing these plans, we have tried to make them consistent with, and complementary to, one another.

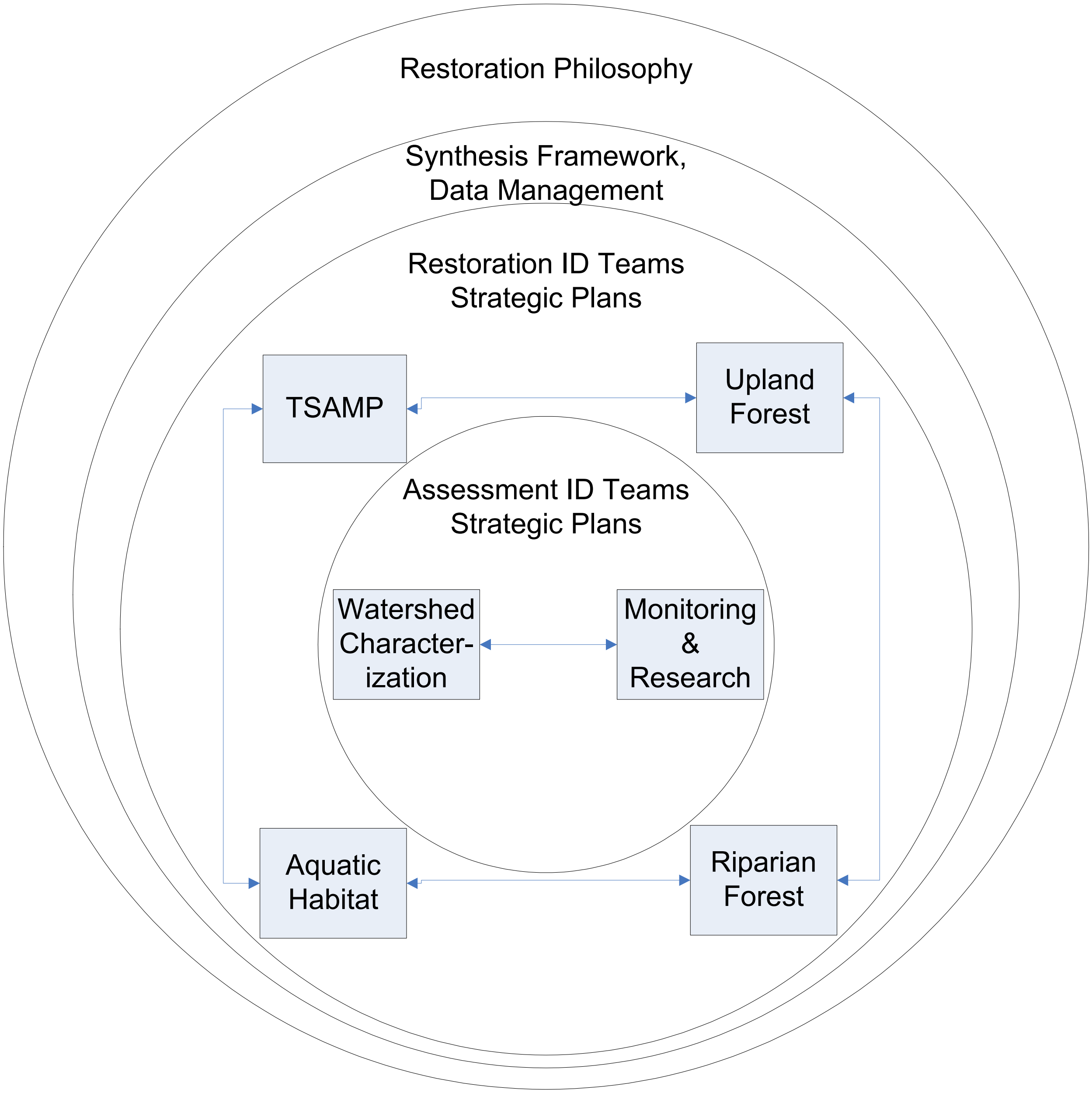

Figure **Error! No text of specified style in document.**-1. Relationship of riparian restoration to other restoration programs and guiding documents.

Two documents help to unify the three strategic restoration plans. The *Ecosystem Restoration and Management Philosophy for the Cedar River Watershed Habitat Conservation Plan* provides an overarching statement of what restoration means within the CRMW HCP (Chapin *et al.*, 2003) and serves to identify the assumptions underlying how we conduct restoration in the watershed. By making these assumptions explicit we can work from a common understanding that makes the rationale for our decisions more transparent. *A Synthesis Framework for the Cedar River Watershed Habitat Conservation Plan* (Erckmann *et al.*, 2007) provides a landscape template for restoration that directs restoration actions to areas where the most synergistic benefit will be realized and helps to coordinate the planning and implementation of restoration among the different ID teams.

Two additional plans help to coordinate two common activities among all strategic restoration ID teams. The *Strategic Monitoring and Research Plan for the CRMW* provides a framework for monitoring among all CRMW ecosystems, so that we can cost effectively evaluate the effectiveness of restoration actions and track long-term trends in ecosystem conditions (Nickelson *et al.*, 2007). The *Watershed Characterization Strategic Plan* serves to coordinate data acquisition efforts that inform the respective ecosystem restoration efforts (Munro *et al.*, 2007).

1.4. Asset Management Framework

Seattle Public Utilities has been systematically applying a paradigm known as "Asset Management" to the development, operation, maintenance, and replacement of the utility's infrastructure. As defined by SPU, "Asset Management is the meeting of agreed customer and environmental service levels at the lowest life cycle costs." Table 1-1, adapted from the *Synthesis Framework* document, lists the principles of Asset Management as practiced by SPU, and how these principles apply to riparian restoration. This plan sets the stage for implementing the riparian restoration program within an asset management framework. Some Asset Management principles are addressed in specific sections of this document (e.g., benchmarking in Appendix B, risk and uncertainty in Section 2.5.7, asset profiles in sections 2.4 and Appendix A). Other principles have been woven into the strategic approach we are taking toward riparian restoration. In particular, the "measures of success" framework for restoration described and developed in section 2.5 incorporates many Asset Management principles.

Table **Error! No text of specified style in document.**-1. Asset management principles as applied utility-wide and to riparian restoration.

Key Principle	As Applied Generally to Infrastructure Within SPU	As Applied to Riparian Restoration in the CRMW
Benchmarking	The process of identifying and using practices from other organizations to help improve our organization's performance.	Examining practices of other agencies involved in riparian restoration and incorporating relevant practices as appropriate.
Risk Management	Identification and mitigation of risks to the asset system.	Identification and mitigation of risks and threats to riparian ecosystems in the watershed, including risks of undesirable outcomes of management interventions, risks of no action, and risks of external threats (e.g., climate change).
Service Levels	Agreed-upon levels of benefits to be produced by management of the asset.	Meeting goals, objectives, and commitments in the HCP; requirements of applicable laws/ regulations, and standards from other guiding documents.
Life Cycle Analysis	Taking a long-term view that encompasses asset decommissioning, replacement, and operating costs.	Taking a long-term view of ecosystem development and functions and seeking to minimize the need for human subsidies over time.
Asset Profiles	Development of information on the asset system to facilitate informed decisions.	Development and analysis of information on current and desired future conditions of riparian ecosystems in the watershed.
Cost/Benefit Analysis	Comparison of options for development or renewal of an asset with respect to total costs of development and ownership	Comparison of options for restoration to determine which approaches and techniques might yield the greatest ecological benefit for a given investment.
Triple Bottom Line	Delivery of services to produce environmental and social benefits at the lowest life cycle cost.	Meeting HCP commitments in the most cost-effective manner, producing the greatest overall ecological benefit for the least financial investment.

1.5. Strategic Plan Organization

This strategic plan has been organized to clearly lay out the rationale, the approach, and the details for planning and implementing riparian restoration in the CRMW.

- This introduction (Section 1) provides the background and context for riparian restoration in the CRMW.
- Section 2 provides a framework for conducting riparian restoration that provides a brief overview of riparian processes and conditions in the CRMW (2.1 through 2.4) and the "measures of success" framework adapted from The Nature Conservancy (2.5). The "measures of success" framework is a systematic approach to defining restoration needs and objectives and a basis for evaluating the effectiveness of meeting restoration objectives.
- Section 3 lays out the rationale and process for prioritizing riparian restoration projects.
- Section 4 describes how restoration projects are to be planned and implemented.
- Sections 5 and 6 provide a guide for what needs to be done to implement the strategic plan (next steps) and the role of the riparian restoration ID team in that implementation.

Additionally, there are appendices that develop some of the material in the body of the document more fully or supplement the document with more detail.

2. Strategic Framework for Riparian Ecosystem Conservation and Restoration

We believe that the general goal of the riparian component of restoration under the HCP is to:

> *Promote the restoration of ecological processes that create and maintain the natural range of variation in riparian functions and habitat, within the constraints of managing the CRMW as a municipal water supply.*

Riparian functions refers to the roles played by the living and nonliving components of the riparian ecosystem in maintaining the integrity of riparian and adjacent aquatic and upland ecosystems. For example, one riparian function is to provide LWD to streams, which is important for channel forming processes and creating high quality fish habitat. An ecological process is defined here as a series of actions, changes, or functions within an ecosystem that bring about a result. Common ecosystem processes include cycling of water, the cycling of nutrients and organic matter, the flow of energy, and biotic interactions (e.g., predation, succession). The distinction between ecological functions and ecological processes is not always clear, as functions usually exist within the context of one or more processes.

In this section we provide a framework for working toward this goal that begins with describing the key ecological processes that are acting within riparian areas. Also important in building this framework for restoration is an historical understanding of the anthropogenic disturbance that has led to the need for restoration. Based on the ecological processes and history of disturbance in riparian areas of the CRMW, we present a conceptual model for restoring riparian functions, from which the framework for restoration is further developed.

2.1. Definition of Riparian Areas for the CRMW

There is a wide range of definitions of riparian areas depending on different perspectives, regional foci, and purposes (e.g., Gregory & Ashkenas, 1990; Ilhardt *et al.*, 2000; Kovalchik, 1987; Malanson, 1993; Warner & Hendrix, 1984). (See Appendix A for a more detailed discussion of riparian definitions.) We will use an ecosystem-based definition of riparian areas (Ilhardt *et al.*, 2000) that captures the ecological processes important for riparian restoration:

> *Riparian areas are three dimensional ecotones of interactions that include terrestrial and aquatic ecosystems that extend into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable width.*

Following this definition, the riparian area or "zone" can refer to the areas adjacent to streams, lakes, ponds, and some wetlands. Within a watershed, the riparian zone varies in width depending on stream gradient and confinement, floodplain and channel migration zone width, the steepness of adjacent hillslopes, and soil and vegetation conditions.

In addition to an ecosystem-based definition, an operational definition of riparian zones is needed to delineate riparian areas for using a Geographic Information System (GIS), applying remote sensing data, or guiding field work. Operationally, we define the riparian zone as:

The horizontal distance of one site potential tree height (100 year index) measured landward from the outer edge of the shoreline, floodplain, or channel migration zone, whichever is greater.

2.2. Ecosystem Processes in Riparian Areas

As the interface, or ecotone, between terrestrial and aquatic environments, riparian areas are influenced by ecosystem processes occurring throughout the watershed (Naiman *et al.*, 1998). Characteristics and functions of the riparian zone are affected by geomorphic processes controlling valley morphology, mass wasting, and debris flows; floods and channel migration within the stream environment; and biological processes such as forest succession and herbivory. Appendix A contains a more detailed discussion of the concepts summarized in this section.

2.2.1. Physical Processes

At the watershed scale, fluvial and hillslope geomorphic processes are strongly influenced by topographic variability (Montgomery, 1999). Fluvial and hillslope processes, in turn, partly control the variability of riparian and aquatic structure and habitat (Figure 2-1). Sedimentation and water from flooding influences the microclimate, soil characteristics, and vegetation patterns in the riparian zone. Streams also transfer water to the riparian area by elevating the alluvial water table during high flow and routing water through gravel bars and surrounding alluvium. As streams incise or aggrade in response to changes in hillslope, sediment input, and base level conditions, channel and floodplain locations can change thereby altering riparian plant community patterns (National Research Council, 2002). Soil moisture is affected by flooding and the alluvial aquifer (the below ground water table connected to the stream), and soil moisture has secondary effects on mineral cycling. For example, nitrification and mineralization are processes that make nitrogen available to plants and are promoted by moist soils, whereas denitrification (the conversion of mineral nitrogen to N_2 gas) occurs mostly in saturated soils.

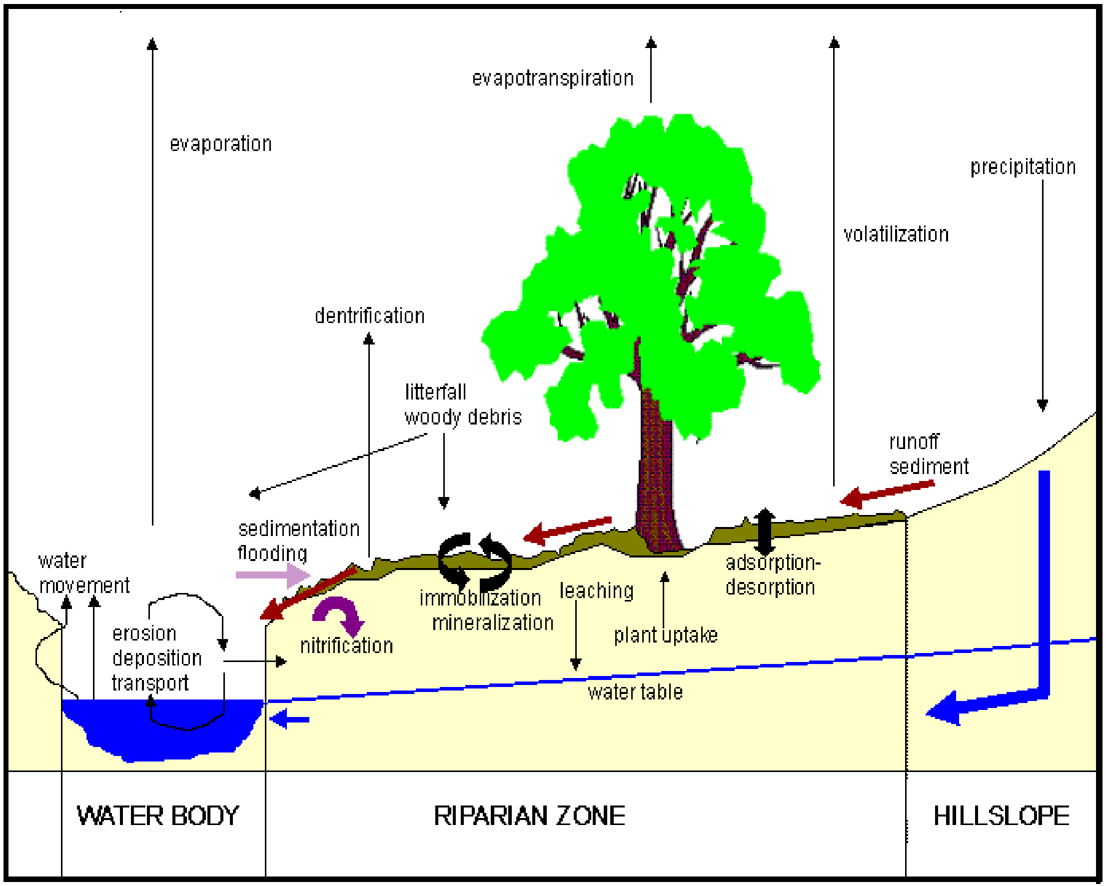

Figure **Error! No text of specified style in document.**-2. Processes occurring within and between a water body, riparian zone, and adjacent hillslope.
(source of figure unknown).

There are a number of disturbance types that uniquely occur in riparian plant communities (Naiman *et al.*, 1998). In steep, low order streams[1], debris flows or torrents strip away riparian vegetation, often down to bedrock. The soil, rock and wood debris from debris flows are typically deposited in alluvial fans at the confluence with a larger stream, often resulting in the burying of existing riparian vegetation. In low gradient, higher order streams, flood flows and channel migration can result in bank erosion, deposition of sediment on floodplains, and physical destruction of vegetation. In addition to these fluvial disturbance agents mentioned above, there are several other important sources of disturbance that affect riparian areas, such as fire, windthrow, insect and disease outbreaks, and timber harvest.

[1] Stream order is a system of describing the location of a stream in the channel network of a watershed. Streams at the headwaters of a watershed start as first order. As smaller order streams merge downstream to become larger streams, stream order increases.

2.2.2. Biological Processes

Riparian vegetation processes depend a great deal on the degree to which the riparian area is affected by fluvial disturbance. Riparian areas unaffected by fluvial processes are similar to upland areas in their disturbance regime, although fire frequency and intensity may be lower in riparian areas due to their topographic position. In contrast, riparian vegetation affected by fluvial disturbance is typically more dynamic than upland vegetation because of the higher disturbance frequency. This dynamic character is reflected, most prominently, in the diversity of successional stages occurring in the riparian zone compared to upland areas. As debris flows, floods, and channel migration destroy older vegetation and create new surfaces for plant establishment, the successional "clock" is reset, and the overall result is a mosaic of plant communities within the riparian zone. Riparian areas also tend to have sharper soil moisture gradients than uplands that also contribute to the higher diversity of riparian plant communities.

Riparian Successional Patterns

Succession on floodplains can have any of several trajectories, which appear to be strongly controlled by soil moisture levels (Fonda, 1974; Hawk & Zobel, 1974; Henderson, 1978; Pabst & Spies, 1999). Where soils are moderately well-drained to somewhat poorly drained, forest succession in riparian areas is similar to that of uplands, with early seral stands of varying levels of deciduous and conifer ultimately developing into conifer-dominated forest (Figure 2-2). Where soil moisture is high, however, competition from deciduous trees and shrubs is very strong, which greatly restricts the establishment and growth of conifers (Figure 2-3). Along confined or entrenched channels with little floodplain, coniferous forest usually extends to the channel edge.

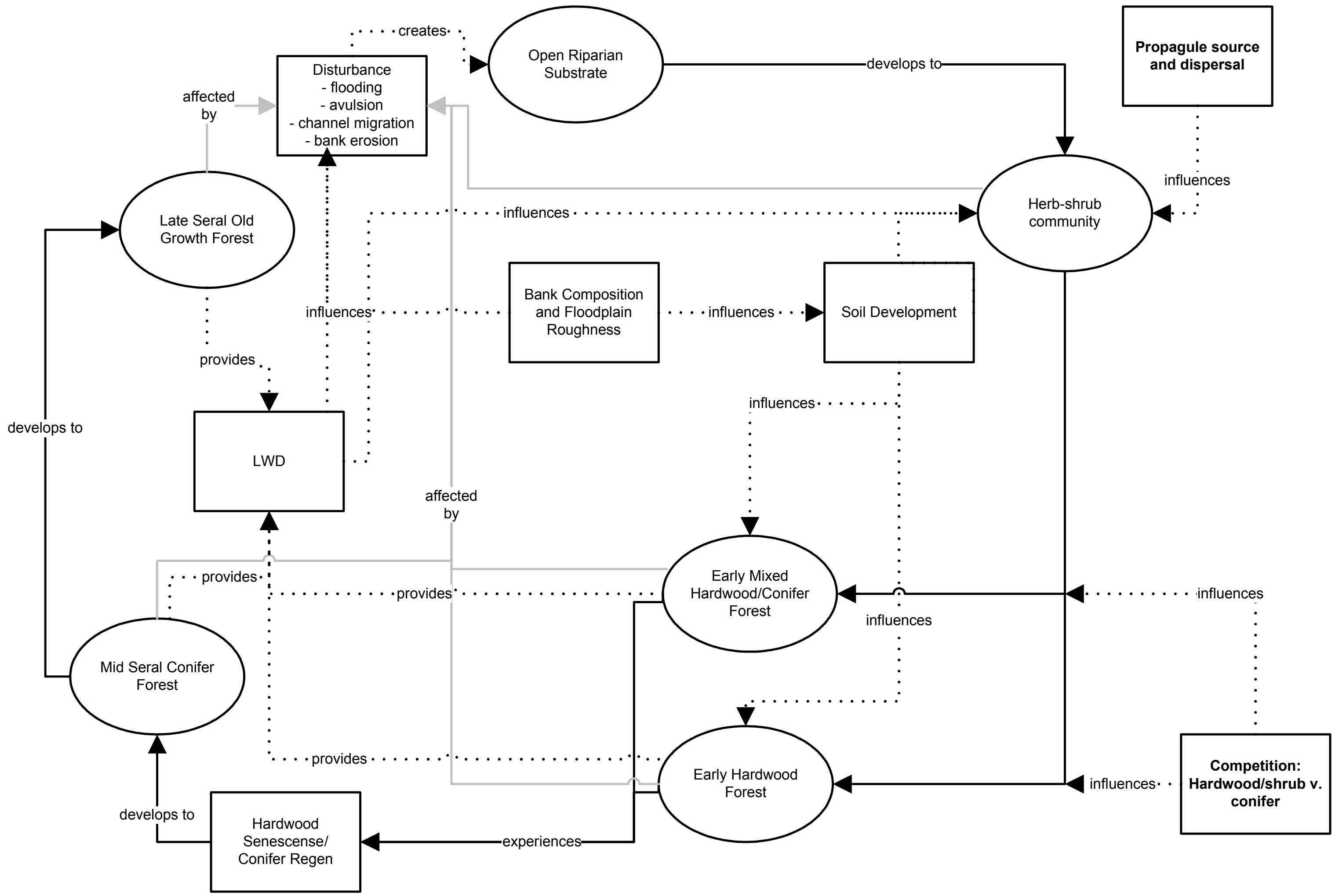

Figure **Error! No text of specified style in document.**-3. Conceptual model of riparian forest succession in low gradient, moderately unconfined stream reaches disturbed by channel migration, avulsion, and flooding.
Successional stages are shown in ovals, with ecosystem processes affecting succession shown in rectangles.

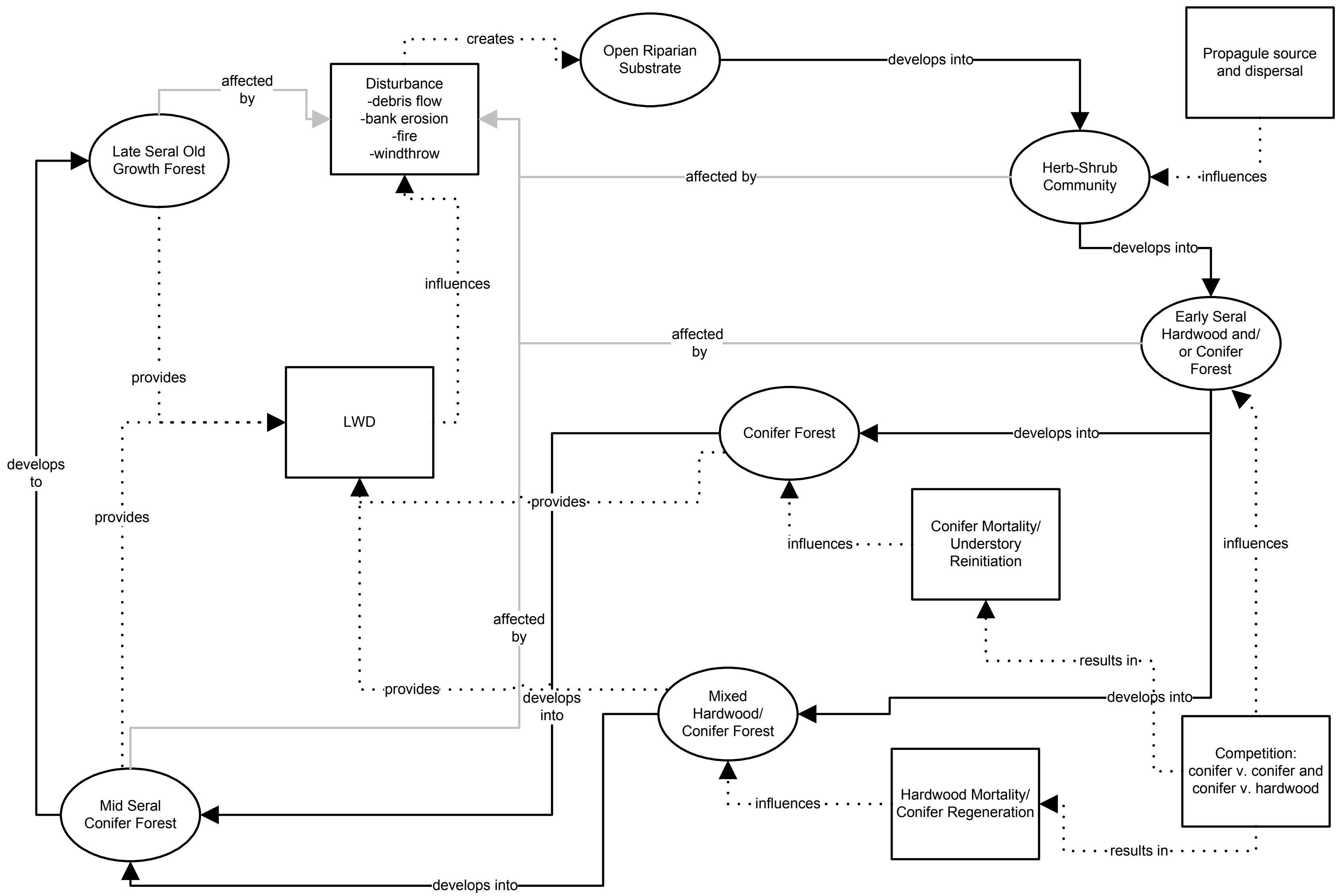

Figure **Error! No text of specified style in document.**-4. Conceptual model of riparian forest succession in steep, confined stream reaches dominated by upland disturbance agents and possible debris flows.
Successional stages are shown in ovals, with ecosystem processes affecting succession shown in rectangles.

Effects of Riparian Vegetation on Fluvial Processes

Riparian areas can have strong effects on fluvial processes, channel morphology, and aquatic habitat (Montgomery & Buffington, 1998). Riparian vegetation and woody debris affect streamflow hydraulics, resulting in secondary effects on sediment transport and deposition. Canopy cover affects water temperature, and nutrient uptake by riparian plants and release of nutrients via litter fall influence water chemistry.

Interactions between Riparian Areas and Fish and Wildlife Populations

Riparian areas directly affect aquatic habitat and species in numerous ways (FEMAT (Forest Ecosystem Management Assessment Team), 1993; Swanson *et al.*, 1982). The influence of riparian vegetation on aquatic habitat as a function of distance from the stream differs according to the effect being considered (Figure 2-4). Trees and shrubs provide shade, resulting in lower water temperature; overhanging shrubs provide cover for fish; and roots stabilize channel banks and provide refuge for fish. Riparian vegetation can be an important source of organic matter to the stream, and riparian trees are the primary source of large woody debris (LWD) in the channel, directly providing aquatic habitat and also affecting channel and habitat-forming processes. Riparian vegetation on floodplain surfaces also promotes sediment storage, resulting in the long term retention of total carbon and nitrogen, which contribute to greater floodplain productivity.

Approximately 29 percent of wildlife species (amphibians, reptiles, birds, and mammals) in the Pacific coastal ecoregion are considered riparian obligates; that is they depend on riparian areas at some point in their life cycle (Kelsey & West, 1998). Since many amphibian species require moist or aquatic habitat, areas adjacent to streams and ponds are often critical to their survival and reproduction. Riparian areas provide important habitat requirements to many resident and migratory birds. Deer and elk depend more on riparian deciduous species when early-successional upland habitat decreases in abundance. Beaver and river otter are riparian obligates and depend on riparian habitat for food and/or nesting.

In turn, fish and wildlife species influence riparian ecosystem processes. In areas heavily browsed by deer and elk, shrub abundance decreases and herb abundance increases. Cycles of beaver activity can lead to cycles of vegetation change as flooding, a higher water table, and sedimentation convert riparian forests to herbaceous and shrub dominated riparian plant communities, with subsequent succession back to forest when the water table drops. When spawning salmon are abundant, marine derived nutrients from carcasses can be transported to riparian areas by high flows or by scavenging animals.

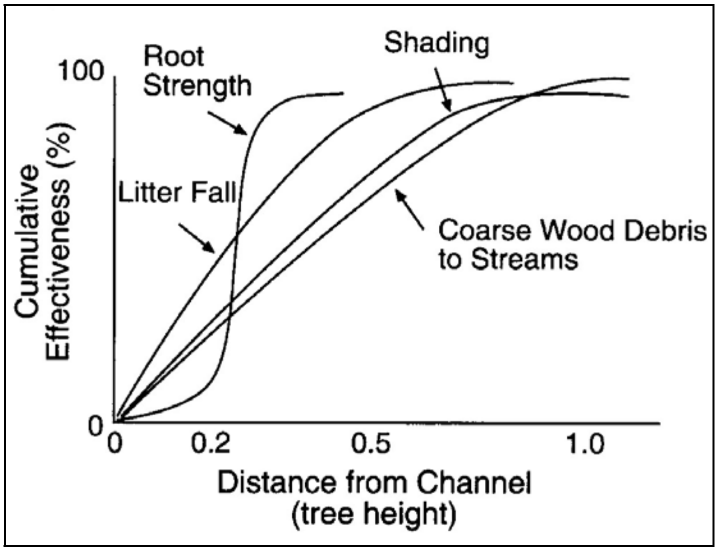

Figure **Error! No text of specified style in document.**-5. Idealized relationship of riparian functional effectiveness versus distance from the channel.
(FEMAT (Forest Ecosystem Management Assessment Team), 1993)

2.3. Classification of Riparian Areas within the CRMW

For purposes of this strategic restoration plan, riparian areas in the CRMW are classified by a combination of overstory type and successional stage. The classes and their respective criteria are shown in Table 1.

Although there are other ways to classify riparian areas, this classification scheme is useful for two reasons. One, these classes can be used for mapping riparian areas from remote sensing and field data. Secondly, they represent sets of conditions that have different levels of riparian function, which lead to different strategies and types of restoration treatments. As discussed in section 2.5.1 below, this classification is used in combination with geomorphic mapping units to define riparian restoration targets.

Table **Error! No text of specified style in document.**-2. Classification of riparian cover types for strategic restoration plan.

Cover Type	Criteria[1]
Young conifer	> 70% conifer, stand age <30 years
Mid-seral conifer	> 70% conifer, stand age >30 years and <120 years
Late seral-old growth conifer	> 70% conifer, stand age > 120 years
Deciduous	> 70% deciduous
Mixed deciduous-conifer	> 30% deciduous and conifer
Shrub	< 30% tree cover; > 50% shrub cover
Herb	<30% tree cover, >50% herb cover, < 50% shrub cover

[1] Criteria are defined as percent canopy cover and stand age. In forested areas, cover may also be measured on the ground as basal area.

2.4. History of Anthropogenic Disturbance and Landscape Transformation

2.4.1. Pre-Settlement Conditions of CRMW Riparian Zones

An understanding of pre-settlement conditions (i.e., prior to disturbance by Euro-Americans) is useful because it provides a reference to a naturally functioning ecosystem unaffected by timber harvest, road building, water regulation, and other impacts of modern society. Since the CRMW encompasses an altitudinal range of approximately 5,000 feet and considerable variation in geologic and topographic characteristics, pre-settlement riparian conditions no doubt varied considerably over the watershed, just as they do now. Based on inferences derived from generally known relationships between ecological processes and geomorphic and topographic characteristics, and limited documented evidence, we can develop a reasonable picture of riparian conditions in the CRMW prior to Euro-American settlement. A detailed discussion of pre-settlement riparian conditions in the CRMW can be found in Appendix A.

In the upper CRMW above Chester Morse Lake, the mainstem Cedar River and lower Rex River had well-developed floodplains and likely had a significant deciduous component, in addition to having very productive old-growth conifer forests on terraces. Riparian areas along steeper tributary streams were probably late-seral to old growth conifer-dominated stands, depending on the time since the last catastrophic fire.

In the lower CRMW, the entrenchment of both the mainstem Cedar River and Taylor Creek into glaciofluvial terraces restricted the development of broad, fluvially disturbed floodplains and channel-migration zones. Consequently, the amount of deciduous trees in lower watershed riparian forests may have been significantly less than in the upper CRMW . Along tributaries (e.g., Webster, Rock, and Williams creeks), much of the terrain is relatively low-relief and there may have been considerable floodplain wetland areas created by beaver dams and LWD, which likely supported extensive deciduous trees and western redcedar “swamps.”

Riparian areas around lake and pond shores likely varied depending on the slope of the shore, elevation, and water-body size. Higher elevation lakes currently surrounded by late-seral, old-growth forest (e.g., Findley Lake) provide a good reference for pre-settlement conditions – a mix of shrubs, conifers, and wetland meadows. Around Cedar Lake (the natural lake that existed prior to the construction of the Masonry Dam and its renaming to Chester Morse Lake), conifer forests likely extended down to shoreline on steeper slopes, with deciduous trees and some conifers (e.g., Sitka spruce and western redcedar) in wetter shorelines and deltas. Walsh Lake was likely quite marshy around its perimeter, similar to its condition today.

2.4.2. Anthropogenic Effects on Riparian Conditions in CRMW

Impacts to riparian areas in the CRMW from humans prior to settlement by Euro-Americans were likely minimal. Settlement in the watershed began as early as 1858, but extensive timber harvest did not begin until after 1900. Timber harvest generally progressed from the western portion of the watershed eastward to higher elevations during the early 1900s, and by 1930 forests in the lower CRMW, around Chester Morse Lake, and up the Cedar River to Roaring Creek were clearcut. Clearcutting of the higher slopes in the upper watershed continued until the 1990s. During the course of the CRMW’s logging history and its use for water and power supply, over 600 miles of road were constructed. There has also been removal of large woody debris from some stream reaches.

The harvest of timber and construction of roads had a variety of direct and indirect effects on riparian areas. Direct effects included the removal of riparian coniferous forest and their replacement by early successional plant communities, often dominated by deciduous species or dense young conifers. One of the most important indirect effects of timber harvest and road building on riparian areas has been the increase in debris flow frequency on steeper slopes (Foster Wheeler Environmental Corporation, 1995). As described above, debris flows result in the removal of riparian vegetation, scouring of stream channels and the input of sediment to the stream. Since timber harvest had already removed most of the large wood, psot-harvest debris flows resulted in little delivery of LWD to downstream stream reaches.

Construction of the Masonry Dam in 1916 resulted in flow regulation of the Cedar River and an increase in the lake level of historic Cedar Lake. Annual fluctuation in lake level increased from a few feet under pre-dam conditions to over 30 feet following dam construction.

Ecological Consequences of Human Impacts

Although a thorough characterization of the CRMW has yet to be completed, we can make some reasonable hypotheses about how land-use activities of Euro-Americans from the late 19th century to the present have impacted CRMW riparian areas. Wide-scale harvest of riparian forests in the watershed has resulted in a shift from mature conifer-dominated riparian forest vegetation to the current prevalence of early to mid-successional stages. These early to mid-successional riparian forests are characterized by smaller trees, less heterogeneous forest structure, and probably greater proportion of deciduous-dominated riparian communities. Strong competition from deciduous trees and shrubs has resulted in a low rate of conifer establishment and growth in some riparian areas. Conifer regeneration may also be reduced due to less coarse woody debris substrate (i.e., fewer nurse logs) and low conifer seed availability where recent, extensive harvest has eliminated seed sources (Beach & Halpern, 2001).

This alteration of riparian areas has, in turn, affected aquatic habitats by:

- reducing the rate of large wood recruitment and associated habitat forming processes,
- removing shade, potentially increasing water temperature and primary productivity,
- changing the nature and quantity of litter input,
- reducing root strength along stream banks, and
- reducing the retention times for nutrients and sediment in the active channel and historic floodplains.

Debris flows have resulted in the scour of riparian forest adjacent to channels and deposited sediment downstream, affecting riparian and aquatic areas, although the extent of this disturbance type is relatively small. Debris flows can also have downstream effects, such as destabilizing lower stream reaches. Recent channel braiding, possibly resulting from increased sediment input from debris flows, has caused widespread fluvial disturbance in one reach along the Cedar River above Chester Morse Lake.

Riparian plant communities on the deltas of the Cedar and Rex rivers as they flow into Chester Morse Lake were inundated by the increased lake level after the construction of the Masonry Dam. These deltas now support extensive sedge and willow communities, but the extent of similar plant communities prior to increased lake level is unknown. Rises in lake level and increases in the fluctuation of lake levels have had a major impact on riparian areas along the Cedar and Rex river deltas (Raedeke and Associates, 1997).

Removal of large wood from streams and the loss of large wood recruitment may have reduced the rate of channel migration or avulsion in some low gradient CRMW streams. On the other hand, loss of riparian trees and increased sediment inputs have contributed to channel instability, as described above. Reduced channel movement would have led to reduced levels of floodplain disturbance, resulting in creation of less riparian and aquatic habitat heterogeneity. In the Cedar River below Cedar Falls, flow regulation and the removal of in-channel large woody debris has contributed to reduced levels of riparian habitat-forming processes, although the river's narrow floodplain and channel migration zone provide relatively little opportunity for riparian habitat complexity, even under a natural disturbance regime.

Based on this general analysis of anthropogenic disturbance, we can make a preliminary assessment of reduced ecological function in riparian areas that have significant impacts on aquatic habitat. These reduced functions include: (1) lack of large conifer trees that contribute to inchannel large wood recruitment and shade (2) bank instability due to reduced root strength or disruption of natural stream flow-sediment processes, (3) loss of shade and change in hydrology to wetland and pond habitat; and (4) hillslope instability triggered by timber harvest and road construction. In addition to these impacts to aquatic areas, there are reduced ecological functions of CRMW riparian areas pertaining to wildlife habitat and large-scale landscape complexity.

2.5. The "Measures of Success" Framework for Riparian Restoration

SPU's Watershed Ecosystems section has incorporated a framework for ecosystem restoration developed by The Nature Conservancy, sometimes referred to as the "Measures of Success" framework (Parrish *et al.*, 2003). Brown (Brown, 2003) further developed this framework as a model for CRMW restoration. Paraphrasing from these two sources, major steps in this approach can be described as:

1. Identify restoration targets.
2. Identify key ecological attributes for each restoration target.
3. Develop a conceptual model for each restoration target
4. Define acceptable range of variation for future conditions.
5. Assess the current status of restoration targets.
6. Identify strategies for achieving desired future conditions.
7. Assess the success of strategies to achieve desired future conditions.

In this section we develop these components in building a "Measures of Success" framework for riparian restoration in the CRMW.

2.5.1. Riparian Restoration Targets

We use the term "restoration targets" to refer to a set of riparian areas that differ from another functional level, restoration need, and dominant physical and biotic processes. This is somewhat different from the TNC "Measures of Success" framework, which uses the term "conservation targets" and defines them as "…a limited number of species, natural communities, or entire ecological systems that are chosen to represent the biodiversity of a conservation landscape or protected area" (Parrish et al. 2003). For our purposes, restoration targets do not represent the biodiversity of the protected area (i.e., the CRMW), but comprise the different types of riparian areas needing restoration within the CRMW.

The classification of riparian areas provided in Section 2.3 are used as the basis for identifying riparian restoration targets. Each of these cover types has associated levels of different ecological functions (e.g., large woody debris recruitment, shade, bank stability), and it is restoring ecological functions that is a central focus of the CRMW HCP riparian restoration program. Because riparian ecological functions are also directly related to adjacent aquatic conditions, we can further define restoration targets by the stream or aquatic geomorphic setting. We have identified six different stream-wetland geomorphic settings as additional criteria for defining the set of riparian restoration targets in the CRMW. These geomorphic settings are related to classification systems for streams and wetlands developed for the CRMW, which are described in detail in Bohle *et al.*, 2007).

Not every riparian cover type is found in every geomorphic setting, nor are all riparian cover types expected to be treated by restoration actions. Consequently, we have reduced the set of restoration targets to those riparian cover types and geomorphic settings within which we might reasonably expect to be conducting restoration based on need and feasibility. Table 2.3 shows the set of riparian conservation targets that we will address further in this strategic riparian restoration plan.

Table **Error! No text of specified style in document.**-3. Riparian restoration targets for the Cedar River Municipal Watershed.

<table>
<tr><th>Geomorphic Settings</th><th>Disturbance Regime</th><th>GMU[1]</th><th>Restoration Targets:
Riparian Cover Types</th></tr>
<tr><td>Terrace/hillslope</td><td>Bank erosion, windthrow</td><td>1-5, 9-15</td><td rowspan="2">Early seral conifer
Mid-seral conifer
Mixed deciduous-conifer
Deciduous</td></tr>
<tr><td>Headwater streams</td><td>Mass wasting</td><td>6</td></tr>
<tr><td>Floodplain/ CMZ</td><td>Flooding, avulsion</td><td>9, 10, 12, 14</td><td rowspan="2">Mixed deciduous-conifer
Deciduous</td></tr>
<tr><td>Alluvial Fan</td><td>Debris flows</td><td>8</td></tr>
<tr><td>Riverine, flow-through wetlands</td><td>Beaver - flooding</td><td>15</td><td rowspan="2">Mixed deciduous-conifer
Deciduous
Early seral conifer
Mid-seral conifer</td></tr>
<tr><td>Depressional wetlands</td><td>Inundation, windthrow</td><td>Depressional Wetlands (open and closed)</td></tr>
</table>

[1] GMU = geomorphic mapping unit (Bohle et al. 2007)

2.5.2. Key Attributes and Indicators of Riparian Restoration Targets

In the TNC "Measures of Success" framework, each conservation target has particular biological and physical characteristics that distinguish it from other targets, control the types and rates of ecological processes, and determine the levels of functions that it provides. Those defining characteristics that are pivotal to the persistence of the conservation target and influence a host of other characteristics are termed "key ecological attributes." Within the framework, measurable indicators of these key ecological attributes are used as the basis to evaluate the current status and the success of conservation efforts for each target (steps 5 and 7 above).

In adapting the TNC "Measures of Success" framework to restoration of CRMW riparian areas, we focus on several, specific riparian functions as the key ecological attributes for characterizing the present condition and evaluating success of restoration efforts. This follows Brown (2003) in her application of Parrish et al. (2003) to the CRMW, where several of the examples of attributes were ecological functions (see "Step 3" in section on Streams and Riparian Forests). Because we expect our restoration to be primarily directed at restoring riparian ecological functions, or, alternatively, at the ecological processes that lead to a recovery of those functions, indicators of these functions would seem to be good measures of current status and restoration success. (It may be useful here for the reader to again refer back to the discussion of ecological functions and processes provided at the beginning of Section 2.)

We have selected a set of key ecological functions as attributes that we believe are likely the most important for riparian areas of the CRMW, given its current condition and location in the foothills and mountains of the Central Cascades (Table 2-4). The key functions of LWD recruitment, shade, channel stability, and nutrient cycling are directly related to the interdependencies between riparian forests and aquatic ecosystems, including streams, ponds, and wetlands. Providing structural complexity is a function that riparian forests have in supporting terrestrial species and biodiversity, similar to functions of upland forests.

Table 2-4 also shows a suite of indicators that can be used to describe and quantify levels of each key function. The measurement of these indicators is central to several of the subsequent steps in the "Measures of Success"-based framework, including the definition of desired future conditions, assessment of existing conditions, and the assessment of restoration success. That is, these indicators are used as surrogates for how well a particular riparian area is providing the range of key ecological functions.

Table Error! No text of specified style in document.**-4. Key ecological attributes (functions) and associated indicators for CRMW riparian restoration targets.**

Key Ecological Attributes	Applicable Restoration Targets	Reach-scale Indicators	Stand-scale Indicators
Recruitment of LWD to aquatic habitat	♦ Floodplain/CMZ ♦ Terrace/hillslope ♦ Headwater streams ♦ Depressional wetlands	♦ % of reach in different cover types ♦ Tree height	♦ Tree species composition ♦ DBH ♦ Tree height ♦ Tree density
Providing shade to aquatic habitat	♦ Floodplain/CMZ ♦ Terrace/hillslope ♦ Headwater streams ♦ Riverine flow-through wetlands ♦ Depressional wetlands	♦ % of reach in different cover types ♦ Tree height	♦ Tree species composition ♦ Tree height
Maintaining channel stability	♦ Floodplain/CMZ ♦ Terrace/hillslope ♦ Headwater streams	♦ % of CMZ occupied by large trees	♦ % of CMZ occupied by large trees
Cycling of nutrients	♦ Floodplain/CMZ ♦ Terrace/hillslope ♦ Riverine flow-through wetlands	♦ % of reach in different cover types	
Providing structural complexity (terrestrial habitat)	♦ Floodplain/CMZ ♦ Terrace/hillslop	♦ Structural complexity index	♦ Structural complexity index ♦ Tree, shrub, and herb composition ♦ DBH
Providing forage for beaver	♦ Floodplain/CMZ ♦ Riverine flow-through wetlands	♦ % of reach in different cover types	♦ Percent willow, alder cover

2.5.3. Conceptual Models for Riparian Conservation Targets

Conceptual models were developed for all of the riparian restoration targets (riparian cover types within particular geomorphic settings) listed in Table 2-2. Conceptual models are useful for explicitly laying out the assumptions and hypotheses that underlie our understanding of how a particular ecological system (i.e., restoration target) works and how restoration might alter that system.

These conceptual models were developed from a general model template that relates current conditions (and levels of associated key functions) to disturbance history, site characteristics, and vegetation and watershed processes (Figure 2-5). The model template shows how future conditions are potentially affected by natural processes and restoration actions to result in future levels of key functions. Trajectories toward future conditions can be the result of natural processes only (no active restoration actions taken), or the result of natural processes and specified active restoration actions. An example of one conceptual model (deciduous-dominated riparian forests in floodplains and alluvial fans) is shown in Figure 2-6. The entire set of conceptual models is found in Appendix C.

The conceptual models are intended to show only the major factors that influence the successional development and key ecological functions of a particular riparian conservation target. There are undoubtedly many other factors that are also influencing the ecological system of each conservation target, but these conceptual models focus on those ecological processes that most control how levels of key functions change through time. By specifying which factors we believe are strongly influencing riparian succession within a specific geomorphic setting, we are making explicit our assumptions and hypotheses about how this particular type of riparian forest develops and functions.

Using the example shown in Figure 2-6, the conceptual model for deciduous-dominated stands in floodplains and alluvial fans begins with the two major sources of disturbance, timber harvest and fluvial disturbance that initiated the development of this type of forest. The key site characteristics that lead to deciduous-dominated forests in this setting are a high amount of surface disturbance (from both timber harvest and fluvial processes) and relatively high soil moisture levels. Early successional processes that are important in the development of a deciduous-dominated stand are seed rain (alder seed is likely to be more abundant than conifer seed) and the much higher growth and competitive ability of alder compared to conifers where soil moisture levels are relatively high.

We can make general predictions of current levels of key ecological functions in such a deciduous-dominated riparian stands in this setting. Currently, functional level is low for most functions (far right column of "level of key functions"). Typically, alder-dominated stands undergo substantial tree mortality at a stand age of 80 to 100 years). If these stands are untreated and have an understory dominated by salmonberry, we hypothesize that they will develop into areas of persistent shrub cover, with decreasing abundance of deciduous trees. If these stands are treated, say by understory clearing and underplanting of conifers, we expect them to develop a conifer component leading to a mixed conifer-deciduous stand, and ultimately to a conifer-dominated stand. Each of these alternative trajectories has associated levels of key riparian functions (treated stands in left column, untreated stands in middle column, current condition in right column), which we predict in the conceptual model. Finally, since these riparian forests occur in floodplains and alluvial fans, future fluvial disturbance may result in their return to early successional conditions.

"Walking through" the conceptual models for the other restoration targets would illuminate our assumptions and hypotheses about how disturbance, site characteristics, natural processes, and restoration influence riparian succession and key functions in other settings. We can use these models in prioritizing areas for restoration and in designing specific restoration treatments.

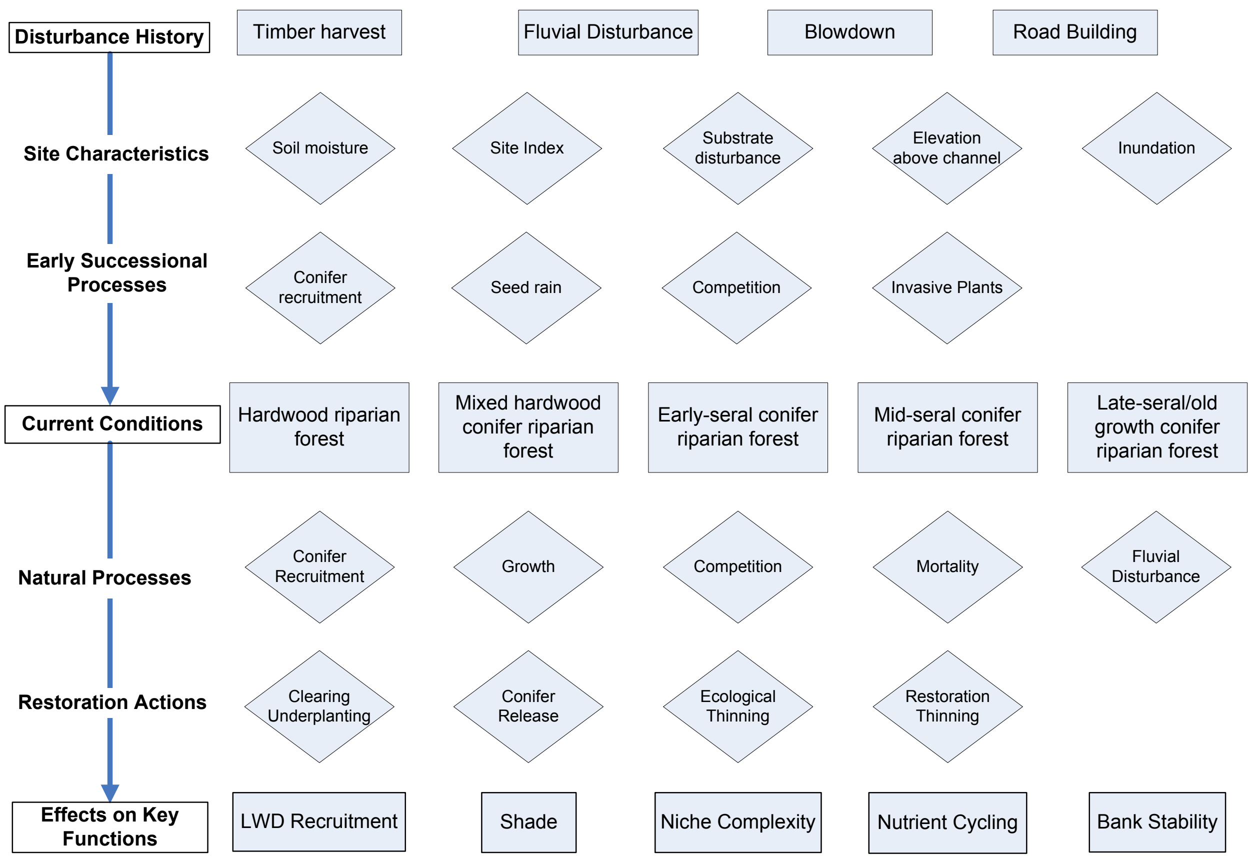

Figure **Error! No text of specified style in document.**-6. Template for developing conceptual models of restoration targets.

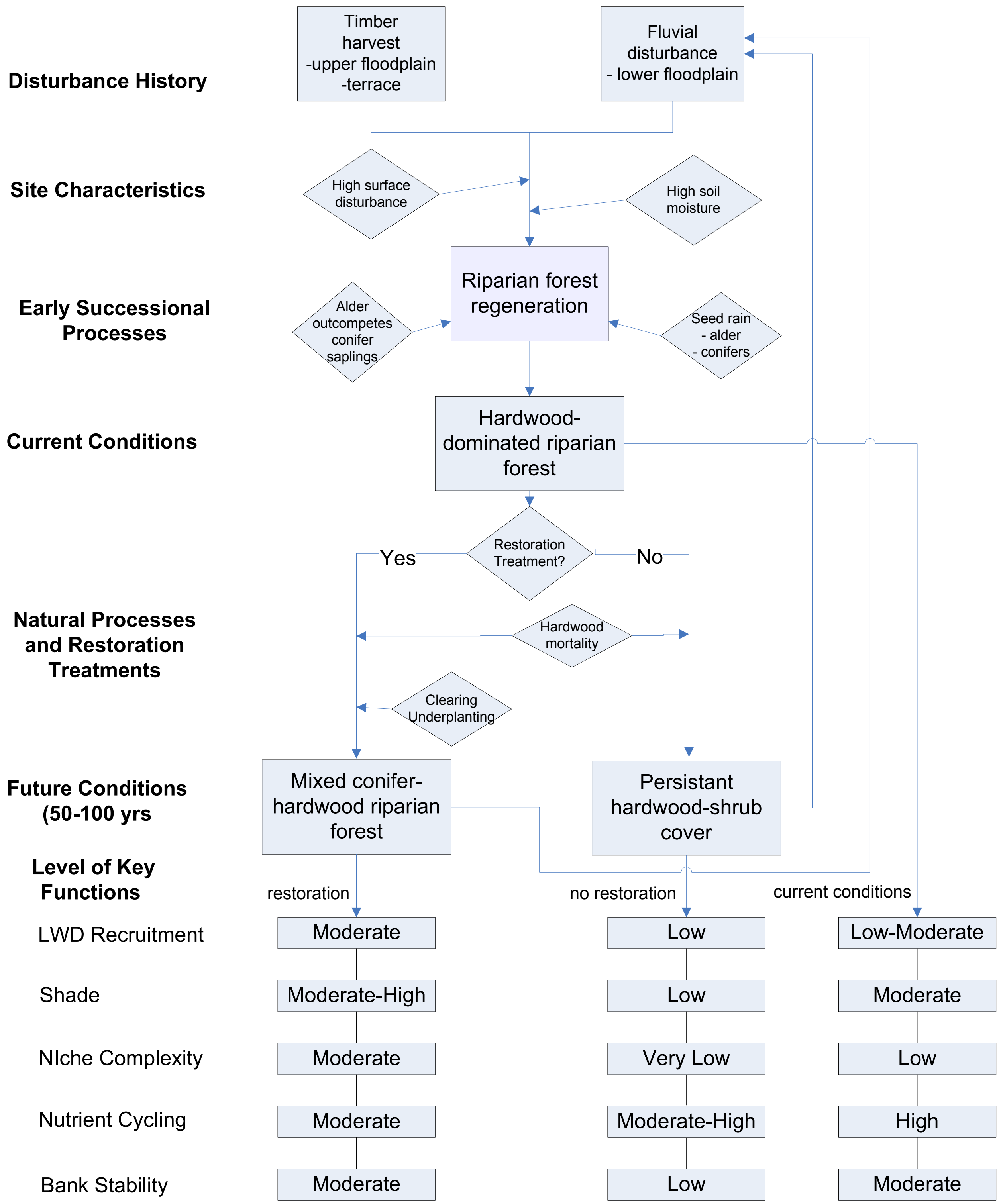

Figure **Error! No text of specified style in document.**-7. Example of a restoration target conceptual model (deciduous/floodplains).
See text for further explanation.

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2.5.4. Desired Future Conditions

Desired future conditions (DFCs) represent our objectives for riparian functional level in the CRMW. To be useful, DFCs need to be quantifiable and tied directly to key attributes and indicators (Section 2.5.2). In addition to providing criteria for the success of restoration actions, DFCs also provide a basis to evaluate the need for restoration. That is, they can be used as part of the prioritization process (see Section 3).

Use of DFCs here, differs somewhat from the concept of "acceptable range of variation" used by Parrish et al. (2003). Parrish et al. define the "acceptable range of variation" of an indicator as that which "...will ensure the long-term persistence of the target" and which is the "minimum criteria for conservation of the target". In the CRMW the persistence and conservation of riparian areas are not threatened, because the HCP has established an ecological reserve in the watershed where no development or timber harvest will occur until at least 2050. Under the HCP, SPU's efforts are directed at improving riparian functions, and DFCs should be developed within this restoration context.

DFCs need to be developed for the list of key ecological attributes (i.e., functions) with associated indicators specific to each restoration target as shown in Table 2-4. Variation among riparian areas in stand age, geomorphic setting, disturbance history, and site index (a measure of site productivity) result in the need for DFCs that encompass the natural temporal and spatial variation in the riparian landscape. The identification of different restoration targets accounts for some of this variation, and the TNC's concept of an "acceptable range of variation" is also useful for addressing the issue of intrinsic variability in conditions among riparian areas. Because most riparian areas in the CRMW are in an early to mid-successional condition, DFCs need to be considered specific to stand age and seral stage. In other words, DFCs could be defined as successional trajectories, which have a changing range of acceptable variation as stands develop. For each indicator shown in Table 2-4, we will describe a quantified range specific to each restoration target and where appropriate specific to seral stage (e.g., tree diameter). The identification of DFCs remains as a next step in implementing this plan, and when they are developed they will be found in Appendix D..

Data Used to Quantify Desired Future Conditions

Although we have not yet quantified DFCs, we can lay out how we expect to determine the acceptable range of variation for each indicator. Reference stands, which are forests that have developed after natural disturbance without human influence (e.g, post-fire salvage or planting), are one source of information for DFCs. Data from reference stands of different ages yields a description of the trajectory a stand follows as it develops into old-growth riparian forest on its own. In CRMW riparian areas, restoration actions are intended to alter successional trajectories to increase the rate at which riparian areas develop functional capability (e.g., provide LWD to streams). Thus, reference stands can be used to create specifications for, and evaluate progress towards, desired future conditions.

Due to past management history, reference stands are limited in the CRMW and in the Pacific Northwest as a whole. There are some old-growth riparian stands in the CRMW that can be used for developing reference stand characteristics. In addition, younger stands that we judge to be moving adequately towards desired conditions (based on such measures as species composition, tree growth rates, and tree heights) can be used as surrogate reference stands.

We can also use literature from riparian areas in other locations in the Pacific coastal ecoregion (i.e., west of the Cascade crest in Oregon, Washington, and British Columbia). Differences within this region with respect to climate, elevation, watershed size, and disturbance history make it somewhat problematic in extrapolating to the CRMW, but data from other studies can be useful for setting ranges.

Another approach is to use the results of modeling forest growth to examine possible trajectories of riparian stands during their recovery from disturbance. Using the U.S. Forest Service, Forest Vegetation Simulator (FVS) we have modeled the development of riparian stands in the lower watershed, with calibration provided by the riparian permanent plot data set. Initial results provide some insight into differences in development among cover types, but some adjustment of input parameters is needed to improve the simulations and make them useful for deriving expected values for DFCs.

Uncertainties and Threats in Reaching Desired Future Conditions

Uncertainties and threats could undermine strategies to achieve stated conservation goals or limit our ability to reach DFCs. Uncertainties have been identified where there is limited knowledge of riparian ecological processes and functions or the outcomes of a specific restoration technique. These uncertainties represent knowledge gaps and are listed in Table 2-6 along with strategies for addressing them.

Invasive species are a significant threat to some riparian areas in the CRMW. We are working to control the spread of and eliminate some targeted patches of Bohemian knotweed (*Polygonum x bohemicum [cuspidatum x sachalinense]*). We have also begun removal and planting projects in patches of non-native blackberry with the goal of increasing the diversity of potentially competitive native species in areas of critical habitat. The Riparian ID team will work closely with the Invasive Plants ID team to identify priority projects and monitor completed projects.

Another potential threat to the forested ecosystems of the watershed is climate change. However, we cannot reliably predict how, when, or if, climate change will significantly alter our riparian forests. To best hedge our bets until a long-term strategy for climate change is developed, we will continue to use a variety of species when implementing planting projects in the watershed – with the assumption that the more species established, the more resilient a given site will be to climate change.

2.5.5. Current Conditions of Key Attributes and Indicators

Assessing the current conditions of our key indicators allows us to see how they compare to the acceptable range of variability along the successional trajectory of CRMW riparian forests. There are several relevant data sets that describe the current conditions of the riparian areas in the CRMW (Table 2-5). Some of these data sets are needed to characterize current conditions of indicators listed in Table 2.4 (e.g., cover type and LiDAR), while others provide useful information about other processes directly affecting riparian areas (e.g., disturbance history). Table 2.6 shows the specific data sources that we anticipate using to quantify each indicator and the current status of each data source.

Critical Knowledge Gaps in Attributes and Indicators

We have identified eight critical knowledge gaps to fill in order to adequately quantify the indicators for key ecological attributes (i.e., functions) in riparian areas (Tables 2-6, 2-7). For all of these indicators we seek to know the current range of variability, rather than just a mean value. Completing all of the data sources, filling the identified knowledge gaps, and finishing the characterization of current conditions from these data are one of the "next steps" needed to implement this strategic plan (see Section 5).

Table Error! No text of specified style in document.**-5. Available data sets to characterize CRMW conditions.**

Data Sets	Data Source and Characteristics
Cover type	classified MASTER data set (remote sensing data)
LiDAR	data obtained from King County; can be used to determine stream gradient, floodplain topography, channel confinement, tree height, and possibly tree density
Permanent sampling plots	sixty-one 900m^2 plots on lower gradient reaches established in 2003-2005
Stand age(TBS layer)	based on watershed records and tree coring in selected stands
Channel type	GMU classification based on watershed analysis (Foster Wheeler 1995)
Wetland classification	hydrogeomorphic classification of wetlands
Soil type	from Natural Resource Conservation Service soil survey
Geology	surface geology from published geological maps within GIS database
Stream habitat type	field sampling based upon the USFS Region 6 standard methods
Mass wasting frequency:	mapping of mass wasting events from 1989-1991 aerial photographs (Foster Wheeler 1995)
Disturbance history	watershed analysis (Foster Wheeler 1995) has general description by subbasin of channels affected by debris flows, floods, and channel movement

Table Error! No text of specified style in document.**-6. Data needed for quantifying indicators of key ecological attributes in riparian areas.**

Key Ecological Attributes (Functions)	Indicator	Data Source	Status	Knowledge Gaps[1]
Potential LWD Recruitment Shade Structural complexity	Tree species composition	Remote sensing - classified Master data	Complete (data are at resolution of cover types, but no data available for higher resolution)	R1
Potential LWD Recruitment Structural complexity	DBH	Riparian permanent sampling plots LiDAR	Small sample, need to extrapolate	R2
Potential LWD Recruitment Shade Structural complexity	Tree height	LiDAR derived map of canopy height Riparian permanent sampling plots	Complete – field verification needed Small sample, need to extrapolate	R3
Potential LWD Recruitment Shade Structural complexity	Tree density	LiDAR derived map of tree density Riparian permanent sampling plots	In progress Small sample, need to extrapolate	R4
Structural complexity	Shrub and herb composition	Riparian permanent sampling plots	Small sample, need to extrapolate	R5
Structural complexity	Canopy layers	LiDAR derived map of of canopy roughnessdensity	In progress	R6
Structural complexity	Gap size/density	LiDAR derived map of gaps	In progress	R7
Nutrient cycling	% deciduous and deciduous/conifer cover	Remote sensing - classified Master data	Complete	R1
Channel stability	% of CMZ occupied by large trees	Remote sensing - classified Master data LiDAR derived map of tree height	Complete Complete – field verification needed	R1
Beaver Forage	Percent willow/alder cover	Surveys of flow through wetlands	No data acquired	R8

Table Error! No text of specified style in document.**-7. Plan for implementing research actions and filling knowledge gaps of current riparian forest conditions.**

Research/Monitoring Need (from Table _)	Approach	Lead Staff	Status/ Timeline for Completion	Constraints (money or expertise)	Collaboration/ Other Opportunities
R1:What is the distribution of riparian cover types by geomorphic setting categories within high priority reaches ?	Use cover type classification of MASTER data to determine areas of cover type by GMU.	Riparian ID team lead	completed	None	Same analysis will provide information to upland forest restoration
R2: What is the mean and variance of DBH for identified high priority reaches?	Use plot data to extrapolate to cover/geomorphic type and to develop regressions of tree height v. dbh that can be applied to LiDAR tree height analysis	Riparian ID team lead	12/08	None	Technique could be applied to upland forest restoration.
R3: What is the mean and variance of tree height for identified high priority subbasins and reaches?	Analyze LiDAR-derived tree heights over relevant GMU stratification of reach types.	Riparian ID team lead	12/08	None	Technique could be applied to upland forest restoration.
R4: What is the mean and variance of tree density for identified high priority subbasins and reaches?	Analyze LiDAR-derived tree densities over relevant GMU stratification of reach types.	Riparian ID team lead	12/08	Analysis not yet fully developed?	Analysis now being developed for upland forest restoration.
R5: In high priority reaches where structural complexity is an important function, what is the diversity of herb and shrub species?	Use plot data to extrapolate to cover/geomorphic type.	Riparian ID team lead	12/08	None	Technique could be applied to upland forest restoration.
R6: In high priority reaches where structural complexity is an important function, what is the degree of vertical structural diversity?	Structural diversity index based on ratio of canopy surface area to ground surface area.	Riparian ID team lead	12/08	None	Analysis now being developed for upland forest restoration??
R7: In high priority reaches where structural complexity is an important function, what is the degree of horizontal structural diversity?	LiDAR derived tree height MASTER data classification	Riparian ID team lead	12/08	None	Analysis developed for upland forest restoration –complete?
R8: What is the amount of willow cover in individual flow-through riverine wetlands?	Inventory important flow-through wetlands and estimate willow abundance.	Riparian ID team lead	12/08	Budget source not identified	

2.5.6. Available Riparian Restoration Treatments and Rationale

There are two basic restoration strategies for riparian areas in the CRMW, passive and active restoration. Because the watershed under the HCP is effectively an ecological reserve, natural recovery, or passive restoration, is the default for the 50 year HCP period. Active restoration includes several possible treatments to apply where we believe intervention is needed and cost effective.

Passive Restoration

Passive, or natural, restoration entails halting the activities that are causing degradation or preventing recovery and letting the ecosystem recover on its own (Kauffman *et al.*, 1997). Halting commercial timber harvest and decommissioning and improving roads under the HCP, eliminated the biggest sources of riparian degradation in the CRMW. Passive restoration does not mean neglect or ignoring a problem situation. Instead, using thoughtful analysis and planning, passive restoration requires identifying areas where removing the cause of degradation will be sufficient, or the most cost effective strategy, for recovery (DellaSala *et al.*, 2003). By identifying those areas and ecosystem components that are not recovering adequately under passive management, we can better target our resources for active restoration to where they are most critically needed.

Active Restoration

The HCP identified three restoration techniques for use in restoring riparian areas within the CRMW: conifer underplanting, ecological thinning, and restoration thinning. These techniques are intended to accelerate the establishment and growth of conifers in riparian stands, which will provide a source of future large wood for streams and provide shade to help maintain lower stream or lake water temperature. In addition they can be designed to increase structural complexity. Road decommissioning in riparian areas also contributes to riparian restoration goals.

Planting. There are two reasons to use planting as a restoration tool. First, planting can be used to increase species diversity in riparian areas where the species composition is low due to past management (e.g., clearcutting all conifers, removing nurse logs that allow for conifer regeneration, planting where invasive species have taken over a site). Second, planting can be used to increase the abundance of targeted species to augment or replace natural regeneration, such as where conifer reestablishment is significantly hindered by dense shrub communities that developed as a result of past land use. Planting projects to date have been in riparian areas with little to no conifer regeneration. These forests bordered streams where LWD is important for fish habitat and regulating stream processes.

Thinning. Thinning is a tool both for areas with small diameter trees and for larger, more mature forests. In younger forests with smaller trees, thinning will involve reducing stem densities to a level that will accelerate tree growth (restoration thinning). This may be in a mix of skips and gaps and will include fuel treatments as appropriate. In older forests, thinning will still aim to increase the growth rate of trees, but it will also focus to a greater extent on increasing habitat complexity with techniques including gap creation and down wood augmentation (ecological thinning). Both types of thinning may at times be followed by planting as appropriate.

2.5.7. Evaluation of Restoration Success

Riparian restoration is a relatively young discipline, which leads to considerable uncertainty about the outcome of different interventions. Evaluation of restoration interventions is critical to reducing this uncertainty and determining if our efforts are achieving the intended results. We intend to conduct the CRMW riparian restoration program within an adaptive management framework to learn from early restoration projects and use these results to reduce uncertainty and improve the effectiveness of riparian restoration interventions. The CRMW strategic monitoring and research plan provides a detailed discussion of how adaptive management is to be applied toward restoration actions under the HCP (Nickelson et al. 2008).

Critical Knowledge Gaps in Restoration Techniques

Because this type of restoration work is relatively new, there are also knowledge gaps around refining the techniques we commonly use in riparian restoration. Planting techniques are an area with high opportunity for experimentation and creativity. Questions we need to address in refining restoration techniques include:

- How large an area needs to have competing vegetation cleared and how frequently do clearings need to be maintained?
- What is the relative effectiveness of different mulching methods and where is mulching appropriate?
- What is the optimum density of planted trees to out-compete surrounding vegetation but allow plantings to still grow well?

Thinning responses have been more thoroughly examined than planting techniques. We can use staff silvicultural expertise and existing literature to develop appropriate riparian thinning prescriptions.

Role of Adaptive Management in Riparian Restoration

Adaptive management is a significant component of the CRMW Strategic Monitoring and Research Plan (Nickelson et al. 2007). As discussed in Section 2.2 of the strategic monitoring plan, adaptive management as it applies to CRMW HCP activities is "…a strategic management approach for implementing habitat restoration or enhancement actions in an experimental context in order to learn more about ecosystem processes being 'treated', with the goal of improving our knowledge about restoration design." We refer the reader to the CRMW Strategic Monitoring and Research Plan for a thorough discussion of how adaptive management is being applied toward restoration actions in the CRMW.

We anticipate that only a few projects will be planned and implemented within a formal adaptive management framework ("active adaptive management"), consisting of experimental treatments that test stated hypotheses about riparian ecosystem processes or restoration techniques. In most projects a less formal approach will be taken that uses only one treatment but where learning and reducing uncertainty are still explicit objectives ("passive adaptive management"). Essential elements in any project with an adaptive management approach include:

- clear statement of objectives,
- explicit hypotheses about outcomes

- implementation of a monitoring and evaluation plan, and
- use of the monitoring results to inform future management decisions.

Figure 2-7 shows a decision tree for applying an adaptive management framework to restoration projects in the CRMW. As described in the CRMW Strategic Monitoring and Research Plan, passive adaptive management assumes a single, "best estimate" model for project design when there is less uncertainty about the outcome. In active adaptive management, higher uncertainty about the ecological outcome of a restoration treatment leads one to try multiple treatments with replicates to rigorously evaluate the effectiveness of alternative treatments.

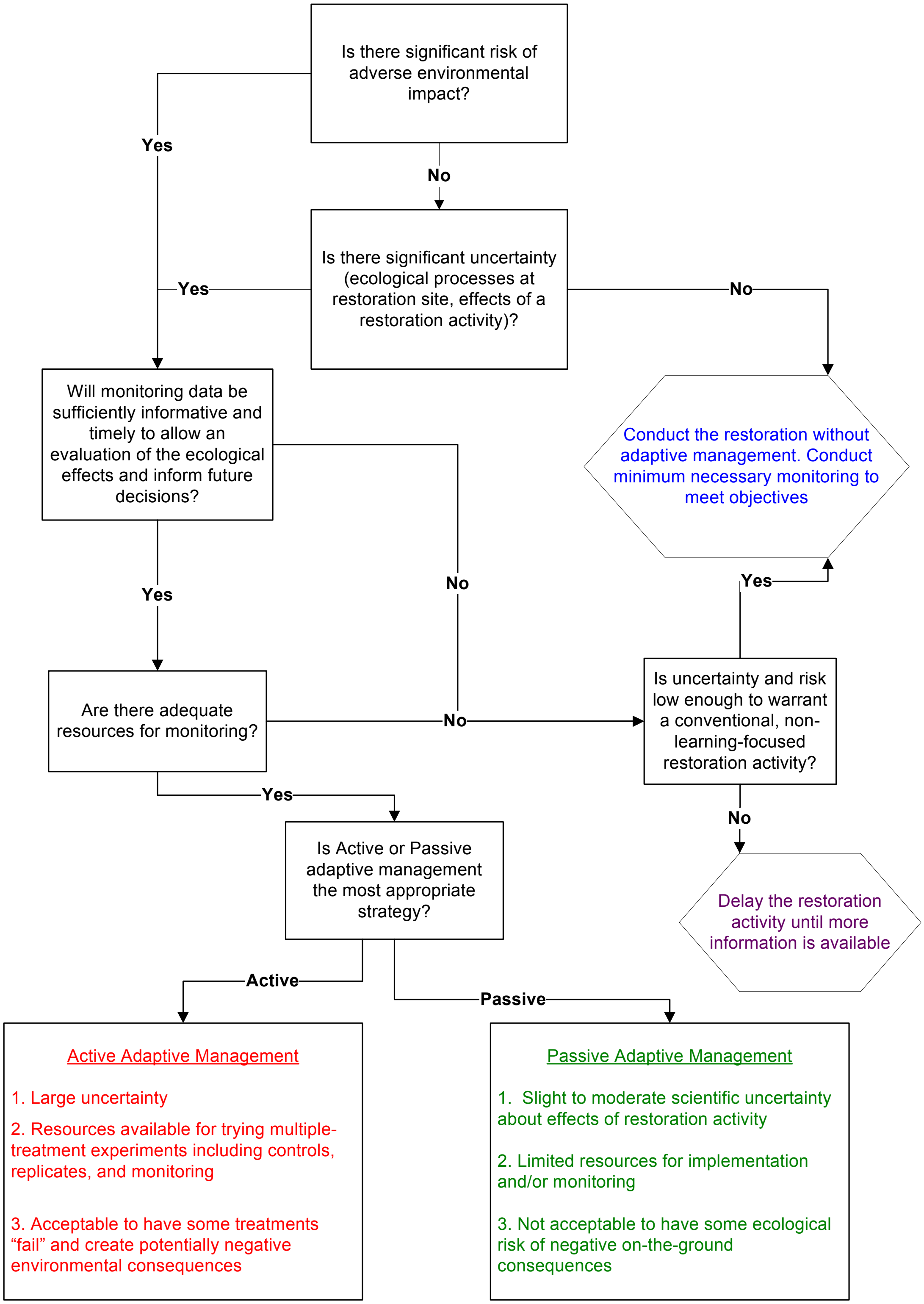

Figure **Error! No text of specified style in document.**-8. Decision process for applying either active or passive adaptive management.
(source: CRMW Strategic Monitoring and Research Plan, Nickelson et al. 2008)

In addition to a project-level application of adaptive management, it can also be applied at a broader program-level. As described by Steven Yaffee (Ecosystem Management Initiative, 2004), there are four steps in applying monitoring and evaluation information toward making ecosystem management decisions:

1. define trigger points or predetermined values for each indicator that signify the need to consider action;
2. identify strategies or actions which might be taken in response to reaching a trigger point;
3. specify who is responsible for making decisions and following through on proposed actions; and
4. establish how this information will be summarized and stored.

Once we have established the DFCs and their acceptable ranges of variation, as well as hypothesized trajectories for different restoration targets, we will define trigger points with a set of corresponding actions. Table 2-8 lays out a plan for applying adaptive management principles to programmatic-level riparian restoration in the CRMW. In this table we identify major uncertainties or questions that we hope to answer by conducting riparian restoration within an adaptive management framework. Associated with these questions are appropriate indicators, trigger points, possible actions if the trigger points are exceeded, and designation of who will evaluate and respond to trigger points.

Implementing a programmatic-level evaluation will require periodic watershed scale data collection similar to what has been done recently to characterize watershed current conditions (see Watershed Characterization Strategic Plan [Munro et al. 2007] and Section 2.5.5 of this plan). Important data sets relevant to evaluating riparian conditions in relation to trigger-points would include remote sensing imagery (e.g., MASTER data, aerial photos), LiDAR, and resampling permanent plots. Future acquisition of data from these sources are recommended as part of the long-term monitoring program.

Table Error! No text of specified style in document.**-8. Plan for applying adaptive management principles to programmatic riparian restoration in the CRMW.**

Question	Indicator and Comparison	Trigger Point	Possible Actions if Trigger Point Exceeded	Who Will Respond
Is current and future LWD recruitment potential adequate in high-priority reaches?	▪ Tree species composition ▪ DBH ▪ Tree height ▪ Tree density	Not known at this time.	Evaluate effectiveness monitoring to see if treatments are achieving objectives. Reprioritize location of restoration actions to target deficient areas.	Riparian and aquatic team leaders
Are we exceeding temperature criteria for key streams? If so, is lack of riparian shade contributing to this problem?	▪ Tree species composition ▪ Tree height ▪ Tree density	Not known at this time.	Evaluate effectiveness monitoring to see if treatments are achieving objectives. Reprioritize location of restoration actions to target deficient areas.	Riparian and aquatic team leaders
Is riparian vegetation on reaches with a history of bank stability problems adequate to avoid future problems?	▪ % of CMZ occupied by large trees	Not known at this time.	Evaluate past actions and determine if there are possible alternative treatments that may achieve objectives.	Riparian and aquatic team leaders
Is riparian vegetation around important pond and wetland habitat providing shade, cover, and other functions?	▪ Tree, shrub, and herb composition ▪ DBH ▪ Tree height ▪ Tree density ▪	Not known at this time.	Evaluate how treatments could better achieve pond and wetland habitat objectives and design/implement appropriate projects.	Riparian team leader and appropriate wildlife biologist.
Is willow present in adequate levels in areas where beaver activity is an important ecological process?	▪ Percent willow cover	Not known at this time.	Evaluate patterns of beaver activity and associated vegetation in the watershed. Increase willow planting if determined to be effective.	Riparian team leader and appropriate wildlife biologist.
	▪			

Question	Indicator and Comparison	Trigger Point	Possible Actions if Trigger Point Exceeded	Who Will Respond
Is the amount and distribution of riparian deciduous trees in the CRMW sufficient with respect to forest development, wildlife habitat, and nutrient cycling?	▪ % deciduous and deciduous/conifer cover	Not known at this time.	Adjust restoration treatments to either increase of decrease amount of deciduous cover in riparian areas.	Riparian team leader and appropriate wildlife biologist.

Data Management
As part of the CRMP strategic monitoring program (Nickelson et al. 2008), we will track riparian monitoring through the Monitoring Tracking Database, which will include the following variables for each project:

- name,
- description,
- location,
- year implemented,
- type of data to be collected;
- anticipated monitoring schedule for the life of the project;
- estimated number of person days required per year,
- funding source (budget #), and
- type of workers required (staff, contractor, intern, volunteer).

In addition, the database will include the locations of the project plan, the monitoring plan, and all data associated with the project.

Data obtained from project specific monitoring will be maintained within a riparian monitoring database. Analyses and reports developed from the riparian monitoring data will be catalogues in the SPU Science Information Catalogue (SIC) and in the Monitoring Tracking Database. Detailed monitoring protocols will be described in Data Acquisition Description Documents specific to each monitoring project (DADDs).

3. Prioritizing Riparian Restoration Projects

Prioritizing riparian sites for restoration treatment is being done at two levels. At a watershed scale, a "landscape synthesis" process (Erckmann et al. 2007) has identified areas where application and synergy of restoration efforts in aquatic, riparian, and terrestrial ecosystems can best occur to produce the greatest ecological benefit. These will be priority areas for potential restoration treatment among all restoration programs in terms of overall landscape position, but without regard to the need for, or feasibility of, restoration in specific locations within these priority areas. At a reach level, this riparian strategic plan addresses how reaches within a "synergy area" will be prioritized for riparian restoration. There may also be analysis of other areas outside of "synergy areas" for possible riparian restoration, but only where there are compelling reasons not captured in the synthesis.

3.1. Landscape Synthesis Prioritization Guidance

The intent of the landscape synthesis process is to "…provide an overall, landscape-level approach to planning restoration in an integrated fashion to most efficiently and effectively achieve the goals of the HCP" (Erckmann et al. 2007). One of the primary goals of the synthesis is to develop a watershed landscape template (or vision) that will be a guide for conservation and restoration of key ecosystems, communities, and species. The landscape template was derived from four themes representing different aspects of watershed biodiversity:

- Fish – which includes the distribution of anadromous salmon and bull trout within the watershed;
- Forest connectivity – which shows areas where existing late seral – old growth or high quality second growth forests occur and where the most effective areas for reconnecting occur;
- Amphibian habitat – includes complexes of aquatic, riparian, and upland areas most likely to be important for amphibians in the watershed;
- Areas adjacent to biodiversity hotspots – which include areas that either have high species diversity or contribute to overall diversity, such as rock, meadows and shrub lands, depressional wetlands, and old growth forest.

Buffers of varying widths were applied to these areas, and overlaps of habitat-buffers among themes were identified within the GIS. Weightings were given to the different themes, and areas of theme overlap were then ranked based on number of overlaps and theme weightings. Areas that rank high in this process are then considered priority areas for upland forest, riparian forest, or aquatic restoration. That is, these areas provide opportunities for synergy of restoration actions among upland, riparian, and aquatic areas. Focusing primarily on these identified "synergy areas", this strategic plan provides a process to prioritize sites (or stream reaches) for implementing riparian restoration actions.

3.2. Identifying and Applying Criteria for Prioritizing Riparian Restoration

To make the prioritization process transparent, it is important to be clear about what criteria are used in prioritizing sites for riparian restoration and how these criteria are used in the decision making process of prioritization. . Four basic criteria have been identified for prioritizing riparian restoration sites, including:

1. **Current and expected state of key attributes (i.e., riparian functions) relative to desired future conditions**

Hypothesized levels of key functions are shown for different restoration targets (riparian cover types within stream geomorphic settings) in Appendix C (also see Section 2.5.3 for discussion). These models predict function level under current conditions, future untreated conditions, and future treated conditions and serve as a starting point for evaluating the first criterion. Thus, sites will be higher priority for active restoration if the level of key functions is significantly lower than the range of levels expected under DFCs.

2. **Importance of a particular key function within a reach,**

The importance of a key function needs to be considered for each reach, which will vary with geomorphic setting and location in the watershed (Table 2-3). For example, LWD recruitment potential is likely to be more important for low-gradient reaches where plane-bed conditions currently exist and where wood plays an important role in channel-forming processes. Or structural complexity is likely to be of high importance in riparian areas where there is less frequent disturbance and also within identified "connectivity" corridors, independent of geomorphic setting Thus, sites will be higher priority for active attempts to restore a key function if that function is highly important in that reach.

3. **Presence of species of concern,**

The presence of anadromous salmonids, bull trout or amphibians is redundant with the "fish" and "amphibian" themes of the synergy areas, which results in these resources being used twice in the prioritization process (i.e., the identification of synergy areas and in prioritization within synergy areas). Since riparian areas are important for creating and maintaining fish and amphibian habitat, that redundancy in the prioritization process is well justified. Thus, sites will be higher priority for active restoration if species of concern are present or likely to be present in the near future. This criterion would also be relevant if and when non "synergy" areas are included in the prioritization process.

4. **Potential response to restoration actions**

Response to potential restoration treatment is an important criterion, because it helps identify areas where benefit to cost ratios should be higher. A lack of response to treatment implies that restoration is not likely to lead to desired outcomes. Lack of treatment response could be due to stand condition (e.g., stands with low crown ratios may not show increases in growth due to thinning) or to geomorphic setting (e.g., planted seedlings may not survive in frequently flooded areas). Thus, sites will only be identified for active restoration if there is a reasonable chance of the treatment being successful in achieving the stated objectives derived from the DFCs.

A formalized decision tree based on these four prioritization criteria is shown in Figure 3-1 One of the main purposes of the decision tree is to make transparent what these necessarily subjective choices are in the prioritization process. The rationale for the particular decision tree used here is as follows:

- The level of key functions is examined first, because current versus expected future condition is fundamental to determining whether restoration is even needed.

- Potential response to restoration is considered next in order to ensure that possible restoration actions have a reasonable chance of achieving desired benefits. If desired outcomes are not likely to occur, there is not much point in implementing a restoration action. Forest growth modeling, as well as professional judgment, can be used to evaluate potential response.
- Importance of key functions is then examined to evaluate the potential benefit of implementing a restoration action. If improving the level of key functions is not considered of high importance, the benefit to cost ratio is not likely to be high.
- Presence of species of concern is considered last in order to identify areas of truly high priority within the management framework of the HCP, which ultimately guides restoration in the CRMW.

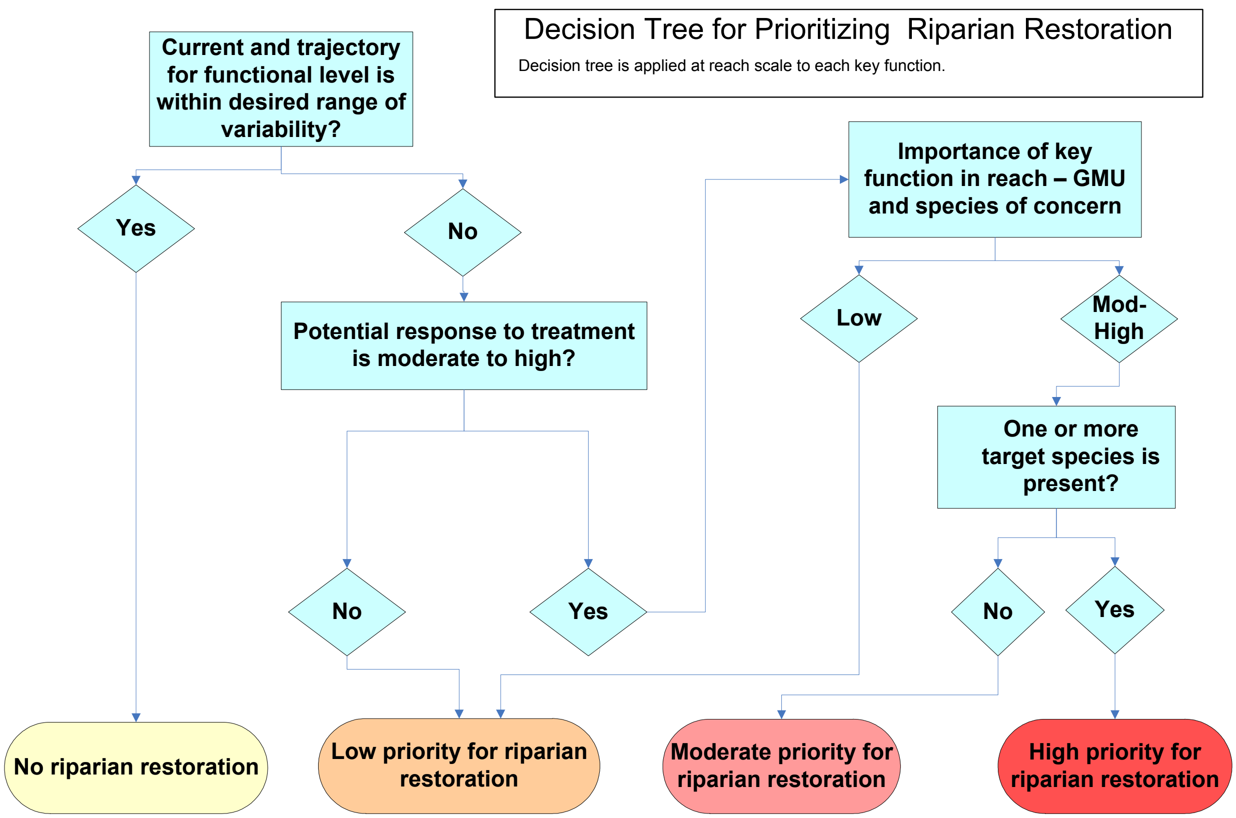

Figure Error! No text of specified style in document.**-9. Decision tree for applying riparian prioritization criteria.**

Table Error! No text of specified style in document.**-9. Importance of key riparian functions for different geomorphic conservation targets**

			Importance of Key Functions			
Conservation Targets: Geomorphic Setting	**Disturbance Regime**	**GMU/HGM**	**LWD Recruitment/Shade**	**Structural Complexity**	**Nutrient Cycling**	**Channel Stability**
Terrace/hillslope	Bank erosion, windthrow, mass wasting	1-5, 9-15	High - decreasing with distance	High – typically most productive sites on landscape	Moderate – interaction with stream decreases with distance	Low – low interaction with channel processes
Headwater streams	Mass wasting	6	Moderate - decreasing with distance	Moderate – similar to surrounding uplands	Moderate – interaction with stream decreases with distance; local effects ramify downstream	High – important for stabilizing toes of inner gorge slopes
Floodplain/ CMZ	Flooding, avulsion	10, 12, 14	High throughout due to potential role in channel and floodplain processes	High – typically most productive sites on landscape	High – interaction with stream high during periodic flooding	Moderate-high – depends on setting, where stream power high then influence more important
Alluvial Fan	Debris flows	8	Moderate – contributes to channel stability	Low – frequent disturbance sets back succession	Low – these surfaces comprise low proportion of riparian landscape	High – channel inherently unstable, so riparian vegetation plays larger role in stability
Flow-through wetlands	Beaver - flooding	15	High – if amphibians present; moderate otherwise	Moderate – wet soils reduce potential for old growth characteristics	High – aquatic productivity likely affected strongly by riparian vegetation	Low – flow velocity not likely to be significant
Depressional wetlands	Inundation, windthrow	---	High – if amphibians present; moderate otherwise	High – adjacency to biodiversity hotspots increases importance	High – aquatic productivity likely affected strongly by riparian vegetation	Low – flow velocity not significant

3.3. Evaluation of Costs versus Benefits

As this work is required under the incidental take permit (HCP), the approach is to identify the most effective and highest priority projects for the cost commitment level (i.e., biggest bang for a given level of dollars). Evaluation of costs versus non-economic benefits is inherently difficult, since units of benefits (e.g., improved level of ecological function) and costs (dollars) are different. Because the prioritization process described in the previous section serves to identify projects based on the level of benefit, the evaluation of benefits is basic to that process. After prioritizing projects and /or sites for riparian restoration, an estimation of costs can be done to select among the higher priority projects/sites for detailed planning and implementation. Weighing estimated costs against priority ranking is a semi-quantitative way to evaluate costs vs. benefits. This process should ensure that our restoration funding goes to those projects and locations where the most benefit can be achieved for a reasonable cost.

3.4. Near-Term List of Riparian Restoration Projects

A near-term list of riparian restoration projects is being developed based on the prioritization process currently in progress. When this list is completed, it will be added to the strategic plan, and it will be updated annually as projects are implemented or newly identified/prioritized. This near-term list is, thus, a next-step to be completed as part of finishing and implementing this strategic restoration plan.

4. Planning and Implementing Riparian Restoration Projects

In this section we describe standards and guidelines for developing project plans and implementing those plans. Since the level of detail in project and implementation plans will be proportionate to the scale and complexity of the project, the way these standards and guidelines are used will vary (i.e., detailed project plans vs. minimal documentation of project actions). In all projects, however, the issues identified below should be considered during the planning process.

4.1. Standards and Guidelines for Planning Riparian Restoration Actions

The detailed project planning process described below should be followed once a riparian restoration project has been identified for implementation. Prioritization of projects occurs through the process identified in Section 3. The project planning process begins with the designation of a project team and team leader (project manager) and designation of team member roles and responsibilities. The project manager is the primary contact and person responsible for successfully planning and implementing the project once it has been identified by the riparian strategic plan restoration ID team. At this time a preliminary schedule for project planning and implementation should be set.

The planning process will include the development of a Project Plan. The following subsections provide guidelines for content of specific sections in the Project Plan (subsection headings are intended as headings of the project plan). For small projects, the amount of detail for each plan component may be very minimal, but it is important to show that each component has been considered in the planning process.

4.1.1. Project Introduction and Statement

The project plan should begin with a brief introduction that describes the type of project and its general location, how the project addresses the larger goals of the HCP and the Riparian Restoration Strategic Plan, and the purpose of the project. Much of the text in the introduction can be “boiler-plate” and used for other project plans.

4.1.2. Site Description

The characteristics of the site should be described and the boundaries of the project delineated on a map. Site characteristics include:

- species composition and abundance (if available, tree basal area/density/regeneration, shrub percent cover could be included),
- geomorphic context (floodplain, terrace, hillslope, valley width),
- site history and recent disturbances,
- soils,
- subbasin context, and
- adjacent aquatic conditions
- other conditions or constraints pertinent to the need for restoration.

4.1.3. Project Description, Objectives, and Justification

Details of the proposed project action, its precise location, and implementation time-frame should be described. More detailed specifications and schedule for project implementation will be developed in the Implementation Plan (Appendix A of the Project Plan).

The specific objectives of the project should be clearly and specifically stated, and tied to the DFCs for riparian restoration. These objectives should be concrete enough to provide quantifiable measures of success. For example, if a thinning project is intended to increase growth rate of riparian conifer trees, the objectives might include a specific percentage increase in radial growth or height compared to trees in unthinnned areas over a given period of time. A conceptual model should be developed that shows how project actions will affect specific ecological structure, functions, and processes to achieve desired outcomes.

Consistent with an adaptive management approach, there should be specified objectives related to learning. That is, reducing uncertainty and increasing our understanding of ecological processes and methods to restore those processes are specific objectives themselves within an adaptive management framework. The adaptive management and monitoring component of the plan (Section 4.1.11) should elaborate on these objectives, including the development of questions and hypotheses for each objective.

Describe how the site was selected and prioritized in relation to other potential projects. What are the reasons for conducting this particular project? How does this project contribute to restoring riparian functions and ecological processes?

4.1.4. Coordination With Other Projects

Any relationship of this project to other riparian, aquatic, upland, or road restoration projects should be described. If the project is part of a subbasin-scale set of projects, a brief description of the subbasin restoration plan should be provided and reference made to any larger plan of which this project is a part.

4.1.5. Evaluation of Potential Effects

An analysis of potential negative impacts and uncertainties should be conducted. Of particular concern is whether the proposed project poses any potential problems to water quality. Potential ecological effects include loss of present or future large wood recruitment with thinning, stream bank destabilization, and invasion by exotic species (e.g., Bohemian knotweed or Himalayan blackberry). Uncertainties include the effects of upslope processes or upstream conditions. For example, if coarse sediment input or transport might result in channel avulsion, riparian projects might be destroyed as the floodplain or channel migration zone is disturbed. The relative certainty of project success needs to be honestly evaluated (e.g., would competition from existing understory threaten the survival of underplanted seedlings?).

4.1.6. Project Mitigation

If there are expected negative effects from the project and these effects can be mitigated, then appropriate mitigation measures should be developed and described. Details for implementing any mitigation measures will be included in the Implementation Plan (Section 4.2.6).

4.1.7. Evaluation of Costs versus Benefits

It is well known that the benefits of ecological restoration projects are difficult to measure in monetary terms to compare with project costs. However, qualitative or quantitative assessment of outcomes can show the relative ecological benefit of the project compared to other projects or alternatives for a given costs. These can then be compared to estimated costs for the projects or alternatives, which provides a basis for cost-benefit analysis and selecting the best projects for a given increment of cost.

Costs should be estimated as well as possible in terms of materials (e.g., seedlings), labor, and equipment. If a project is large and complex, a mechanism of tracking costs (e.g., U-code for project in Time Card) should be in place. The specific program budgets (e.g., Riparian Conifer Underplanting, C00018) that will provide funds for the project should be identified. The impact of this project on program budgets should also be assessed. For example, a project that takes up 80 percent of the annual budget for Riparian Conifer Underplanting might not be such a great idea, or it might be perfectly fine, but this budget impact should be determined with respect to achieving the greatest ecological benefit for the costs over time. This means that projects cannot be evaluated independently, but need to be considered as a set of projects to be completed over a period of years.

An evaluation of project costs versus benefits should be made that describes what is being accomplished for the costs incurred. If the benefits are marginal compared to the costs, or if the certainty of achieving these benefits is low, the implementation of the proposed project should be reconsidered.

4.1.8. Outside Review, Permitting, and Approvals

Riparian restoration projects are subject to several potential county, state, and federal regulations, some of which require specific permits. Early in the planning of a project, applicable regulations and needed permits should be identified. Necessary permits should be applied for when information about the project is sufficient to make the permit application, and time for permit processing should be considered in the project schedule.

If the restoration project involves ecological thinning, where surplus timber will be sold, a City Ordinance for the project may be needed. The project schedule should allow for the time needed to obtain such an ordinance.

It may also be advisable to have the project reviewed by other outside parties at certain stages during its development. Expert review may be helpful if techniques are experimental or if the project is particularly challenging. Depending on the project, it may be advisable to solicit comments by outside interest groups (e.g., tribes, environmental groups, external experts) early in the planning process.

4.1.9. Contract Development

If contracts are needed to implement the plan, responsibility and a schedule for contract writing, bidding, and administration need to be determined.

4.1.10. Adaptive Management and Monitoring Plan

The adaptive management and monitoring plan will be included in the Project Plan. In addition, a monitoring schedule and set of protocols will be developed as Appendix B of the Project plan. This set of monitoring protocols should be included in a centralized CRMW project monitoring file to ensure that future monitoring needs are tracked and coordinated. A centralized CRMW project monitoring file being developed as part of the CRMW Monitoring Program.

As described in Section 2.5.7 above about adaptive management and monitoring, all projects conducted within an adaptive management framework should have a:

- clear statement of objectives,
- explicit hypotheses about outcomes
- implementation of a monitoring and evaluation plan, and
- use of the monitoring results to inform future management decisions.

Since monitoring resources are limited, not all projects can be monitored. The Riparian Restoration ID team has developed a strategic approach to monitoring that has identified key monitoring questions that address present uncertainty in the effectiveness of riparian restoration techniques. The approach then describes a strategy of how many and what kind of projects to monitor tied to relative uncertainty about outcomes and the amount of resources estimated to be available for monitoring. See Appendix E for a description of the strategic monitoring approach for riparian restoration.

4.2. Standards and Guidelines for Implementing Riparian Restoration Projects

An overview of the steps, logistics, and schedule for implementing the restoration action should be described in the project plan. An Implementation Plan may be useful as a stand-alone document and included as Appendix A to the project plan. The Implementation Plan should be written for use in the field by personnel conducting the project. Content of the Implementation Plan should include the following considerations.

4.2.1. Completion of Baseline Monitoring

Details of the monitoring plan are described in the body and Appendix B of the Project Plan, but the dates and brief description of baseline monitoring should be indicated in the Implementation Plan.

4.2.2. Identification and Availability of Needed Resources

Identify all materials, equipment, and labor needed for project implementation and determine the source and availability of all needed resources.

4.2.3. Mobilization, Initiation, Oversight, and Safety

Lay out the logistics of project implementation. Important issues that may need addressing include: staging of equipment and materials, road access, communication with contractors, oversight of contractors or Operations personnel implementing the project, and safety concerns and measures. Specify schedule for project initiation and completion.

4.2.4. Coordination with Other Projects

Specify what projects may need to be coordinated with this one and how that coordination is to take place.

4.2.5. Project Specifications

Specifications developed in the project design should be clearly described so that personnel implementing the project can easily refer to them for guidance during implementation. If contractors are used, these specifications would be included in the contract. Specifications include such things as:

- how trees would be selected and marked for thinning,
- direction of falling,
- how slash or downed trees are to be dealt with,
- size and species for underplanting,
- spacing of seedlings for underplanting,
- any treatment of competing understory vegetation,
- use of browse control materials for planted seedlings, and
- relevant maps and diagrams showing placement of treatment areas, seedlings, wood, etc.

4.2.6. Mitigation Measures

If any mitigation measures are described in the Project Plan (Section 4.1.8), details and specifications for implementing these measures should be described.

4.2.7. Project Closure

Several activities need to be carried out following project implementation. These include:

- Demobilization: Staging areas should be cleaned up, equipment cleaned and returned to storage, extra materials returned to vendor or stored for future use.

- Compliance monitoring and documentation: Monitoring to determine whether specifications of project were complied with. Any changes in project design or specifications should be documented.
- Cost evaluation: Project costs should be documented and evaluated against project budget. Costs include those associated with planning, design, implementation, monitoring, and closure.
- Data management: Data collected for project planning, baseline monitoring, compliance monitoring, costs, and other purposes should be compiled, formatted, and stored in the appropriate hard and soft files, as designated by the CRMW Watershed Characterization ID team.
- Evaluation of any project problems: If any special problems were encountered during implementation of the project, they should be evaluated and documented.
- Debrief of project team: A final project team meeting should be held to provide an accounting of the project completion, discuss any issues that may still be outstanding, and confirm responsibilities for project monitoring.
- Completion of a project "as-built" document.

5. Next Steps

There are several items in this strategic plan that are not yet completed for the plan to be considered finished. Rather than wait until all these pieces are complete, we are publishing this draft of the plan, with the idea that it will be updated as remaining tasks are completed.

5.1. Data Acquisition and Assessment of Current and Desired Future Conditions

Table 2-6 identifies data needed for quantifying current conditions of indicators of key ecological functions in riparian areas. Most of these data needs entail analysis of already acquired data to use in the quantification of particular attributes. There is still some work to fully verify and make operational the use of LiDAR to characterize forest structural attributes. Also, permanent plot data need to be analyzed to extrapolate beyond the sampled stands. For some indicators, we have not yet determined how they will be quantified (e.g., willow cover, vertical structure). We expect to complete most of these data gaps by 2008.

We also need to quantify indicators for desired future conditions. Sources of information for DFCs include data on current conditions in reference stands (i.e., old growth or second growth that is on desired trajectory), information from other areas, and modeling of forest growth.

5.2. Setting Triggers for Long-Term Adaptive Management

The completion of data acquisition and analysis is also needed for determining triggers for long-term adaptive management actions. These triggers will be set as specific values or ranges of indicators for key functions. Before we can set these triggers, we need to now the current range of variability for specific indicators.

5.3. Prioritization

At the completion of this strategic plan working draft (January 2008), the riparian restoration prioritization process is still in progress. The "synergy" layers from the landscape synthesis effort (Erckmann et al. 2007) have been identified and were used to focus further prioritization of riparian restoration areas to select areas (primarily the upper Cedar and Rex River basins and the lower Cedar River/Rock Creek area). Characteristics of these areas with regard to cover type, tree height, and other factors have been compiled and reviewed. A near-term list of projects within these areas will be compiled as a next step, which will be included in Appendix F.

6. Role of the Riparian Restoration Interdisciplinary Team

Upon completion of the Strategic Plan, the ID Team will continue to function as a group to prioritize, plan, and coordinate riparian restoration projects and monitoring. The interdisciplinary composition of the ID team provides a good forum for discussing and evaluating project proposals. Having members of the riparian ID team also on other restoration ID teams helps to coordinate activities among groups, and the ID team leader will participate in annual planning that will include all team leaders.

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Appendix A
The Ecology of Riparian Areas

In this appendix , we provide a definition of riparian areas appropriate to the CRW and discuss the kinds of ecological processes important to riparian areas in the coastal Pacific Northwest ecoregion. We also present an overview of riparian characteristics in the CRW both prior to disturbance following Euroamerican settlement in the late 19th century and under current conditions.

Riparian Defined

The term riparian is derived from the Latin word "riparius, which means "of or belonging to the bank of a river" (Naiman et al. 1998). Numerous riparian definitions have been used that stem from different perspectives, regional foci, and purposes (e.g., Gregory and Ashkenas 1990, Ilhardt et al. 2000, Kovalchik 1987, Malanson 1993, Warner and Hendrix 1984), but there is no universally recognized riparian definition that adequately describes all riparian zones (Fisher et al. 2001). Ilhardt et al. (2000) provide an ecosystem-based definition that captures the ecological processes important for riparian restoration:

> Riparian areas are three dimensional ecotones of interactions that include terrestrial and aquatic ecosystems that extend into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable width.

Following this definition, the riparian area or "zone" can refer to the areas adjacent to streams, lakes, ponds, and some wetlands. Within a watershed, the riparian zone varies in width depending on stream gradient and confinement, floodplain and channel migration zone width, the steepness of adjacent hillslopes, and soil and vegetation conditions.

In addition to an ecosystem-based definition, an operational definition of riparian zones is needed to delineate riparian areas, using a Geographic Information System (GIS), remote sensing, or field work, that will generally include the "three-dimensional ecotones of interaction" as they occur in the CRW. Operationally, we define the riparian zone as:

> *The horizontal distance of one site potential tree height (100 year index) measured landward from the outer edge of the shoreline, floodplain, or channel migration zone, whichever is greater.*

A 100 year index "site potential tree height" is the height the tree of a given species can be expected to grow in 100 years, given specified site conditions that are primarily determined from soil type. Species used to determine the riparian zone width for CRW lands are Douglas fir for areas below 2,500 ft elevation and Pacific silver fir for areas above 2,500 ft elevation. Table 2-1 shows potential tree heights for these two species under different site index classes, which will be used for delineating riparian areas in the CRW. These riparian area widths, however, may be modified based on other site-specific conditions.

Table 1. Site potential tree heights used to delineate riparian areas in the CRW.

Site Class	Site Potential Tree Height (ft)[1]	
	Douglas Fir (<2,500 ft elev.)	**Pacific Silver Fir (> 2,500 ft elev.**
II	250	180
III	200	150
IV	160	120
V	120	90

[1]Site potential tree heights in this table were calculated from growth curves found in (………..) and soil site classes in the Soil Survey of Snoqualmie Pass Area, Parts of King and Pierce Counties, Washington (Natural Resources Conservation Service 1992).

Ecosystem Processes in Riparian Areas

As the interface, or ecotone, between terrestrial and aquatic environments, riparian areas are influenced by ecosystem processes occurring throughout the watershed (Naiman et al. 1998). Characteristics and function of the riparian zone are affected by geological processes controlling valley morphology, mass wasting, and debris flows; floods and channel migration within the stream environment; and forest succession within the riparian and adjacent upland. Moreover, since these physical, chemical, and biological processes interact in complex ways, they must be considered in relation to one another, not as isolated phenomena.

In discussing ecosystem process within riparian areas, it is important to keep in mind their spatial and temporal variability. Spatial variability is a result of differences in geology, climate, and land use across a region (e.g., coastal Oregon versus North Cascade Mountains) and differences in the physical setting within a watershed (e.g., steep headwater areas versus low-gradient alluvial streams, riparian wetlands adjacent to streams versus lacustrine fringe wetlands). Temporal variability of riparian ecological processes is a function of fluvial and hillslope disturbance frequencies ranging from less than a year ($< 10^{o}$yr) to many millennia ($> 10^{3}$ yr).

This section briefly considers several key ecosystem processes that both affect and are affected by riparian areas. Because riparian areas differ greatly between regions, the discussion is restricted to conditions west of the Cascade crest in the mountains and adjacent lowlands of Washington and Oregon. Naimen et al. (1998, 2000) provide excellent, recent overviews of ecological processes in riparian areas in the Pacific coastal ecoregion.

Physical Processes

Geomorphic Context and Physical Habitat

At the watershed scale, geomorphic processes are strongly influenced by topographic variability. Mass wasting and debris-flow processes occur in steep terrain and play a minor role in low-relief regions of the watershed. Topography also controls channel slope, therefore strongly influencing the structure and and network wide variability of in-channel habitat (Montgomery 1999). At a fundamental level, fluvial and hillslope processes control the variability of riparian and aquatic structure and habitat. This variability in habitat type controls the distribution, composition, structure, and functions of riparian and aquatic biological communities.

Fluvial processes (e.g., channel migration, avulsion, and bedload transport) in unconfined lower gradient channels have a multitude of effects on channels and their associated floodplains. They cause:

- the erosion of unconsolidated active channel and floodplain alluvium,
- sediment deposition resulting in new alluvial landforms,
- sediment transport,
- sorting of channel bed materials, and
- transport of nutrients.

Hillslope and fluvial processes shape and influence the riparian environment (Figure 2-1). Sedimentation and water from stream flooding influences the microclimate, soil characteristics, and vegetation patterns in the riparian zone. Streams also transfer water to the riparian area by elevating the alluvial water table during high flow and routing water through gravel bars and surrounding alluvium. As streams incise or aggrade in response to changes in hillslope sediment and base level conditions, changes in channel and floodplain locations can occur that alter riparian plant community patterns (National Research Council 1992).

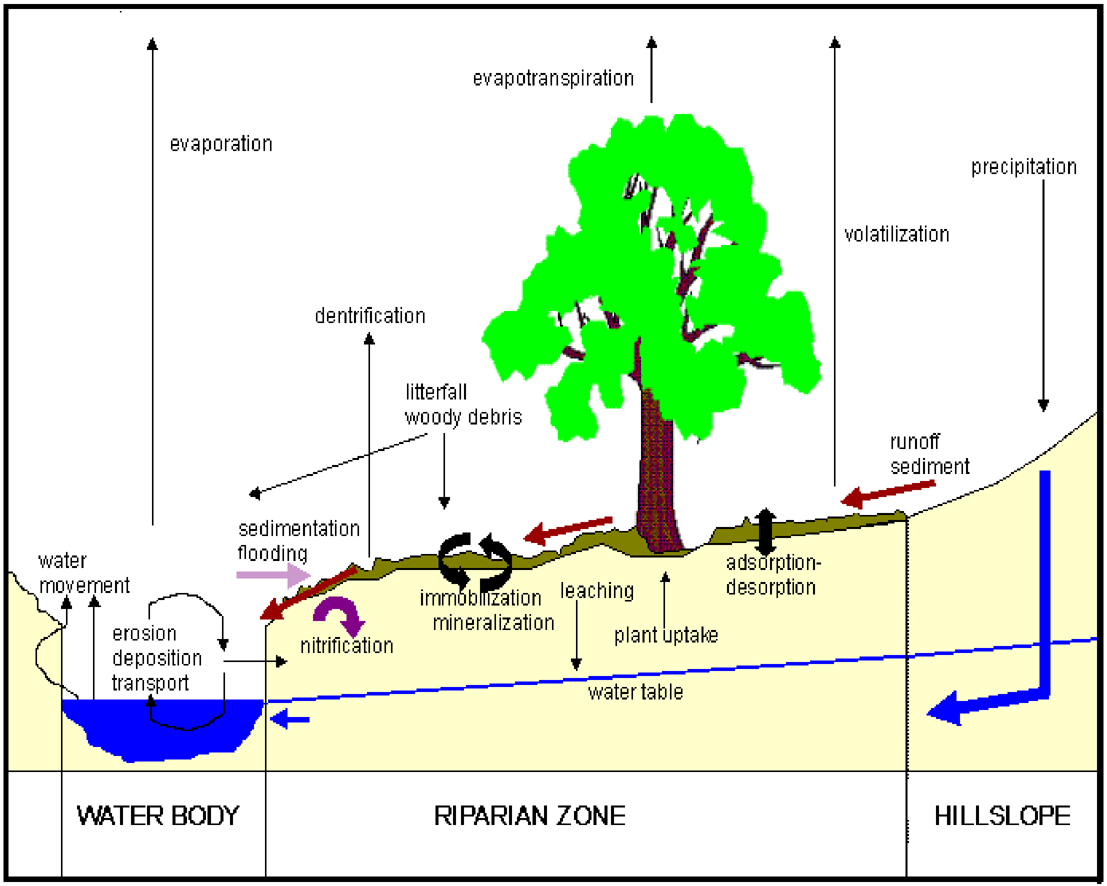

Figure 1. Processes occurring within and between a water body, riparian zone, and adjacent hillslope. (source of figure unknown)

In turn, riparian areas have strong effects on fluvial processes, channel morphology, and aquatic habitat (Montgomery and Buffington 1998). Riparian vegetation affects streamflow hydraulics, resulting in secondary effects on sediment transport and deposition. Riparian root systems increase channel bank stability by increasing streambank shear resistance. Woody debris and sediment inputs from riparian and hillslope areas cause changes in channel roughness, flow resistance, and morphology through localized sediment sorting, deposition, and erosion. Canopy cover and evapotranspiration from riparian plants affect stream temperature and stream flow discharge. Nutrient uptake by riparian plants and release of nutrients via litter fall influence stream water chemistry.

Disturbance Processes Affecting Riparian Areas

There are a number of disturbance types that uniquely occur in riparian plant communities (Naiman et al. 1998). In steep, low order streams[1], debris flows or torrents strip away riparian

[1] Stream order is a system of describing the location of a stream in the channel network of a watershed. Streams at the headwaters of a watershed start as first order. As smaller order streams merge downstream to become larger streams, stream order increases.

vegetation, often down to bedrock. The soil, rock and wood debris from debris flows are typically deposited at the confluence with a larger stream, often resulting in the burying of existing riparian vegetation. These deposits can subsequently be mobilized by high stream flows. In low gradient, higher order streams flood flows can result in bank erosion, deposition of sediment on floodplains, and physical destruction of vegetation. Channel migration and avulsion are also characteristic physical disturbances in less confined alluvial valleys. In addition to these fluvial types, riparian areas are also subject to disturbance events occurring across forested landscapes, such as fire, windthrow, insect and disease outbreaks, and timber harvest. Disturbance types vary in their frequency (e.g., debris flows are less frequent than floods) and intensity. Important ecological effects of these disturbances include:

- the elimination of existing vegetation cover,
- creation of space for colonization by new plants,
- downstream transport of plant propagules,
- deposition or removal of large woody debris, and
- influx of nutrients to riparian soils.

Vegetation Processes

Riparian vegetation is typically more dynamic than upland vegetation because of the relatively high frequency of disturbance resulting from the geological and fluvial processes discussed above. This dynamic character is reflected, most prominently, in the range of successional stages occurring in the riparian zone compared to upland areas. The valley forest mosaic is comprised of patches of varying forest seral stages. Vegetation patch characteristics, such as age, species composition, and structure, are a function of the unique pattern of disturbances that occur in riparian areas. As debris flows, floods, and channel migration destroy older vegetation and create new surfaces for plant establishment, the successional "clock" is reset. The overall result of the riparian disturbance regime is a mosaic of plant communities within a watershed's stream-riparian network and relatively high species diversity compared to uplands.

Riparian plant communities often include areas of wetter soils than upland communities due to influence of the stream and emergence of groundwater at the base of hillslopes. A different array of trees, shrubs, and herbs tend to dominate under these soil conditions compared to those in drier forested areas. However, riparian soils are sometimes quite droughty, where substrates are dominated by coarse gravels and cobbles(Fonda 1974).In addition to the plant species diversity fostered by a mosaic of successional stages, sharp gradients in soil moisture and light in riparian areas further contribute to the higher diversity of riparian plant communities,

Riparian Successional Patterns

In the coastal Pacific Northwest ecoregion, surface disturbance and subsequent plant recolonization in the riparian zone typically lead to an early dominance by hardwood shrubs and trees, such as willow (*Salix* spp.), red alder (*Alnus rubra*), big leaf maple (*Acer macrophyllum*), and cottonwood *(Populus trichocarpa*). These species generally have higher light and moisture requirements than evergreen shrubs and trees, and are adapted to become established and grow in fluvially disturbed sites due to readily dispersed seeds, rapid growth rates, and in the case of alder, the ability to fix nitrogen. A variety of other hardwood shrubs, such as salmonberry (*Rubus spectabilis*), red-osier dogwood (*Cornus sericea*), stink currant (*Ribes bracteosum*), red elderberry (*Sambucus racemosa*), and Pacific ninebark (*Physocarpus capitatus*) are also common in early successional riparian vegetation, and are often persistent at the stream edge where light and moisture remain in abundant supply (Pabst and Spies 1998).

Succession on floodplains and can have any of several trajectories, which appear to be controlled by soil moisture levels (Fonda 1974, Hawk and Zobel 1974, Henderson 1978, Pabst and Spies 1999). Where soils range from moderately well-drained to somewhat poorly drained, forest succession in riparian areas is similar to that of uplands, where early seral hardwood-dominated stands develop into conifer-dominated forest. For example, Sitka spruce (*Picea sitchensis*) dominated first terrace stands on the Olympic Peninsula (Fonda (1974), and Douglas fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) succeed alder stands in the Oregon Cascades (Hawk and Zobel 1974).

Where soil moisture is high, however, due to fine textured soils with a high water table and in seepage areas at the base of slopes, competition from hardwood trees and shrubs is very strong, which greatly restricts the establishment and growth of conifers, even relatively shade tolerant species such as western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and Sitka spruce. Since establishment of conifers in wet riparian areas has been found to be more favorable on rotting logs or stumps, the succession of riparian areas from hardwoods to conifers may be limited by the amount of large down wood (Beach and Halpern 2001, Harmon and Franklin 1989, Pabst and Spies 1998). Some research suggests that the successional trajectory of alder-salmonberry dominated riparian areas may be towards persistent shrub communities, as the relatively short-lived alder dies after an 80 to 100 year lifespan (Henderson 1978, Nierenberg and Hibbs 2000, Pabst and Spies 1998). The length of time since riparian alder-salmonberry stands became widespread following timber harvest, however, is too short to adequately test this hypothesis.

Effects of Geomorphic Processes on Riparian Vegetation Succession

Successional processes in riparian plant communities vary depending on elevation, gradient, fluvial geomorphic surface, and distance from the active channel. The process domain concept Montgomery 1999) is a useful approach to evaluate the effects of these physical variables on riparian successional processes. In collaboration with the Aquatic Restoration ID team, we have identified four major process domains in the CRW characterized by disturbance process type and associated habitat characteristics: 1) hillslopes (i.e., colluvial channels), 2) confined valleys, 3) unconfined valleys, and 4) alluvial/debris fans. (See Section 3.2 for further discussion of process domains).

Steep, colluvial channels do not have stream deposited sediments, have little to no floodplain, and are subject to periodic debris flow events that reinitiate vegetation succession (Naiman et al. 1998). Loss of root strength from timber harvest and failure of logging roads results in higher frequency of debris flows in high gradient, confined channels (Swanson et al. 1987). Since large woody debris helps to retain sediment in steep channels and riparian areas, removal of large wood due to timber harvest may further increase frequency of debris flows and retard stabilization and succession of riparian areas.

Along confined channels, there is relatively little diversity or spatial extent of alluvial surfaces in the riparian zone. The ecotone of terrestrial and aquatic ecosystems is typically narrow along confined channels, with coniferous forest usually extending to the channel edge in the CRW. In unconfined valleys, the erosion and deposition of sediment creates different geomorphic surfaces, such as channel banks, abandoned channels, floodplains, low terraces, and high terraces. Along unconfined channels, floodplains and channel migration zones can include complex surface topography extending hundreds of meters from the channel. Differences in flood frequency and soil moisture across these surface types strongly affect vegetation composition and succession.

The relative abundance of different successional stages and community types within the riparian zone depends on the type, frequency, and magnitude of disturbance. Frequently flooded areas (1.5 to 10 year return interval) typically remain dominated by early successional hardwood shrubs and trees, because of surface disturbance and flooding that periodically kills or removes riparian plants growing on these surfaces (Pabst and Spies 1998, Rot et al. 2000). In floodplains, the probability distribution of stand age has been found to fit a negative exponential model, with a relatively high frequency of young stands and low frequency of old stands (Agee 1988). On terraces, where flooding is less frequent, mid-successional and mature forests dominated by conifers are more likely to develop. The distribution of riparian successional stages can be stable, or there may be alternating periods when early or late successional communties are most abundant. Consequently, to adequately characterize, assess, and restore riparian areas, it is important to consider them within a watershed-wide spatial scale and ecologically meaningful time scales.

Interactions between Riparian Areas and Fish and Wildlife Populations

It is well known that riparian areas are of critical importance to fish and wildlife species. However, the impact that fish and wildlife have on riparian areas is much less appreciated. A thorough understanding of riparian ecological processes requires consideration of interactions in both directions between riparian vegetation and animal species.

Riparian areas directly affect aquatic species in numerous ways (Forest Ecosystem Management Assessment Team [FEMAT] 1993, Swanson et al. 1982). Trees and shrubs provide shade, resulting in lower water temperature that is essential for many aquatic organisms. Overhanging shrubs provide cover for fish, and roots stabilize channel banks and provide refuge for fish. Riparian vegetation is an important source of organic matter to the stream, particularly in smaller streams that receive little sunlight and have low primary production. Riparian trees are the primary source of large woody debris (LWD) in the channel, providing aquatic habitat structure directly, as well as indirectly through the effect of LWD on channel morphology. The influence of riparian vegetation on aquatic habitat as a function of distance from the stream differs according to the effect being considered (Figure 2-2). For many riparian ecological services (root strength, litter fall, shading, LWD input), most of the effect from the riparian area is within one site potential tree height (FEMAT 1993). The influence of riparian vegetation on stream microclimate (air temperature, wind speed, relative humidity), however, has been shown to extend from much farther away (Dong et al. 1998).

Approximately 29 percent of wildlife species (amphibians, reptiles, birds, and mammals) in the Pacific coastal ecoregion are considered riparian obligates; that is they depend on riparian areas at some point in their life cycle (Kelsey and West 1998). Since many amphibian species require moist or aquatic habitat, streamside areas are often critical to their survival and reproduction. Riparian areas provide important habitat requirements to many resident and migratory birds. Resident birds that specialize on aquatic food resources often nest in riparian areas to be in close proximity to feeding areas. Within a generally coniferous dominated landscape, riparian areas provide deciduous tree and shrub habitat that is important for a variety of birds, such as warblers, western tanager, Pacific slope flycatcher, and Swainson's thrush. Deer and elk depend more on riparian deciduous species when early-successional upland habitat decreases in abundance. They also utilize riparian areas for thermal cover and for more nutritious browse during calving in spring and again in late summer when upland browse becomes desiccated. Beaver and river otter are riparian obligates and depend on riparian habitat for food and/or nesting.

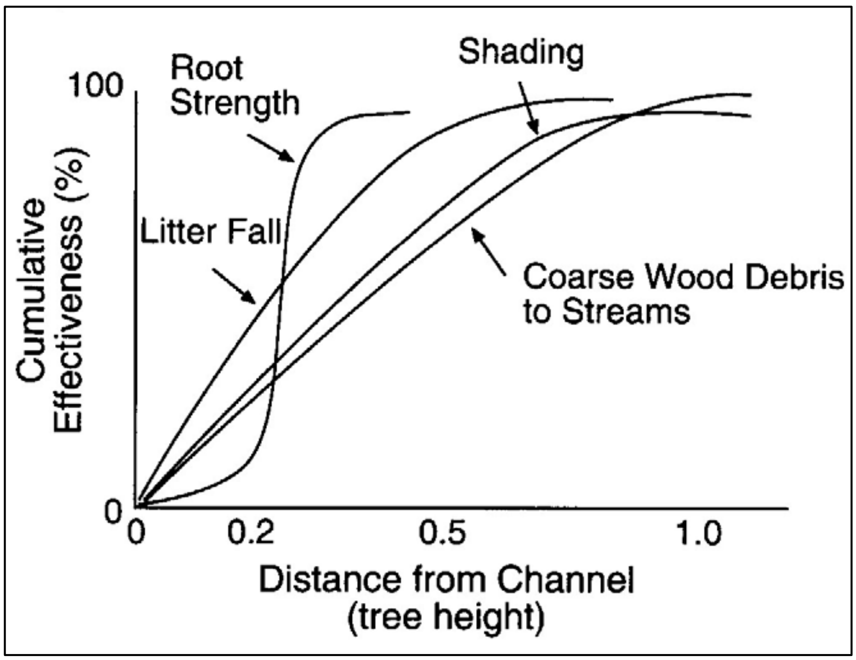

Figure 2. Idealized relationship of riparian effectiveness for individual functions versus distance from the channel. (Forest Ecosystem Management Assessment Team 1993).

In turn, fish and wildlife species influence riparian ecosystem processes (Kelsey and West 1998). Elk and deer can alter riparian vegetation by browsing and trampling. In heavily browsed riparian areas, shrub abundance decreases and herb abundance increases. Beaver are perhaps the most obvious example of how animals can affect riparian areas. The effect of beaver on riparian areas is dramatic when beaver dams result in the flooding and die-back of riparian trees. Cycles of beaver activity can lead to cycles of vegetation change as flooding and a higher water table convert riparian forests to herbaceous and shrub dominated riparian plant communities, with subsequent succession back to forest when the water table drops. Alternatively, they can create entirely new habitat, as when silt and organic matter accumulate behind beaver dams resulting in bog, marsh, or meadow habitat. Thus, it is important to consider the historical as well as the current effects of beaver in interpreting ecological processes in riparian areas.

Recent research has shown that salmon can play an important role in transferring nutrients to riparian areas (Naiman et al. 2000). When salmon return to streams to spawn, they bring nutrients largely accumulated from the ocean. After the salmon spawn and die, marine derived nutrients from carcasses can be transported to riparian areas by high flows, hyporheic movement of water in soils below riparian areas, or by piscivorous scavengers and predators. Studies have shown that 18 to 25 percent of the nitrogen in some riparian plants are from marine sources (Naiman et al. 2000).

Summary of Riparian Conditions and Processes in the CRW

In this section we provide a brief description of CRW riparian conditions and ecological processes as they existed prior and subsequent to settlement by Euroamericans. Our knowledge of pre-settlement and early historical conditions in the CRW is very limited; indeed, one of the objectives of the CRW Watershed Characterization is a more complete understanding of its past ecosystems, as well as of current conditions. Consequently, this discussion is somewhat general and is based on limited local data, regional historical patterns, and reasoned inference from what we know about riparian ecological processes.

A watershed analysis conducted by Foster Wheeler Environmental Corporation (1995) provides the most complete characterization to date of stream and riparian conditions in the watershed and how they have been affected by land-use over the past 100 years. As part of the watershed analysis, a classification system for valleys and streams was created for the entire CRW (Foster Wheeler 1995). Valley type was determined by modifying methods from Metzler and Cupp (1989), and channel type was determined by modifying methods from Rosgen (1985) and Montgomery and Buffington (1993). Using a stratified sampling technique on the 23 valley-channel reach types occurring in the CRW, Foster Wheeler assessed channel and fish habitat conditions and analyzed the potential response of channels and fish habitat to upstream and hillslope inputs. Much of the following description of riparian areas and their physical setting is derived from this watershed analysis.

Within the CRW there are a wide diversity of landforms, ranging from steep mountainous basins formed by alpine glaciers to gently sloping lowlands formed by advances of the continental ice sheets. Elevation range in the watershed is from approximately 500 feet to over 5,000 feet. Stream channels and riparian areas within the watershed show a corresponding wide diversity of characteristics. The watershed can be divided into two geologic regions based on its geomorphic history. The area east of Cedar Falls, referred to as the Upper Watershed, consists of steep mountainous terrain. The stream network varies from steep headwaters formed by alpine glaciers to u-shaped alluvial valley bottoms at the lower reaches of the basin. Chester Morse Lake (formerly called Cedar Lake) is located in an historic lake basin at the lower end of the Upper Watershed. The area west of Cedar Falls (including the Taylor Creek drainage), referred to as the Lower Watershed, consists of thick deposits of recessional outwash and ice-contact deposits at lower elevations, and unglaciated sedimentary or volcanic geology at higher elevations. Thick deposits of recessional outwash and ice-contact deposits create gently sloping terraces in this area. The markedly different geologic histories in the upper and Lower Watersheds have led to very distinctive present day geomorphology (Foster Wheeler 1995). The processes influencing stream channel and riparian development are influenced strongly by these varied geological conditions.

Pre-Settlement Conditions of CRW Riparian Zones

Historically, the CRW landscape was dominated by late successional or old growth coniferous forest, which likely also covered much of the riparian zone. The age of these coniferous forests was primarily a function of time since the last major fire disturbance, with a fire frequency in the range of 230 to 750 for the forest types present in the watershed (Agee 1993). Age of remaining old-growth forest in the watershed ranges from approximately 200 to 800 years. Fire frequency in riparian areas may have been lower, due to their more humid conditions and less vulnerable topographic position (i.e., at the bottom of slopes). Species composition of riparian conifers likely included most of the species now present in the watershed, such as western redcedar, Sitka spruce, western hemlock, Douglas fir, and silver fir.

Within this matrix of coniferous forest, areas dominated by hardwoods, particularly red alder, were probably common within floodplains and other riparian areas subject to relatively frequent fluvial disturbance. Alder shows up continuously and abundantly in a >2,800 year pollen record from Findley Lake (Adams 1973) and in pollen records throughout the Pacific coastal ecoregion since the end of Pleistocene glaciation (e.g., Cwyner 1987, Warona and Whitlock 1995, Whitlock 1992). Additional local data on the pre-settlement occurrence of hardwoods in the CRW comes from botanical analyses of soils from archaeological sites around Chester Morse Lake, which showed remains of alder, maple, poplar (probably black cottonwood), and willow throughout a 9,000 year old record (Stenholm 1993). Aerial photographs from 1930 show that unlogged riparian areas along the upper Cedar River had a hardwood component. From these data, it is clear that alder and other hardwoods have long played a role in early successional plant communities in the Pacific Northwest, including the CRW and neighboring watersheds. Although fire was the most extensive disturbance type leading to alder dominated communities in pre-settlement forests, fluvial disturbance was also a factor in creating early successional plant communities on the landscape and especially in alluvial valleys.

Since the CRW encompasses an altitudinal range of approximately 5,000 feet and considerable variation in geologic and topographic characteristics, the characteristics of pre-settlement riparian areas varied considerably. For discussion purposes riparian areas in the CRW are separated into (1) streams of the Lower Watershed (below Cedar Falls, including the Taylor Creek basin), (2) streams of the Upper Watershed (Cedar and Rex river basins), and (3) lakeshores/wetlands. Both the Lower and Upper Watersheds include the four major fluvial process domains (colluvial/hillslope, confined valleys, unconfined valleys, and alluvial /debris fans) and associated disturbance regimes, as described in Sections 2.2.2 and 3.2. Because of the extensive variation in riparian areas within the CRW, appropriate reference ecosystems as models for restoration will differ among these geographic and process domain categories.

Lower Watershed Streams

Streams in the Lower Watershed include the Cedar River and Taylor, Rock, Webster, Williams, and Steele creeks. Although the Cedar River below Cedar Falls has a relatively low gradient (average 0.7 percent), much of the river is confined by a glaciofluvial terrace and has likely had a narrow floodplain and channel migration zone for many millennia (Foster Wheeler 1995). Consequently, confined reaches of the Cedar River differ from most confined streams, which usually have steeper gradients (> 4.0 percent). Historically, early successional hardwood-dominated riparian forests (red alder, cottonwood, and maple) were probably restricted to floodplains and low terraces that were, and still are, infrequent along this reach of the river. Much of the riparian zone along the lower Cedar River was undoubtedly dominated by large coniferous trees. Although the relative proportions of different species present in pre-settlement riparian forests is not known, Sitka spruce, western redcedar, Douglas fir, and western hemlock were certainly all present.

The tributaries of the Cedar River draining the northern side of the valley include Webster, Rock, Williams, and Steele creeks. These streams originate along the steep, headwater slopes of Taylor Mountain, Brew Hill, and Rattlesnake Mountain within the colluvial and confined alluvial process domains. The headwaters of Williams Creek also includes a low gradient wetland complex that likely also was present prior to Euroamerican settlement. Since the upper reaches of these streams were subject to infrequent mass wasting events and debris flows, a few scattered, linear patches of early successional hardwood shrubs and trees were probably present at any particular time. In most places, forests along these steep tributary reaches were undoubtedly dominated by coniferous species to near the channel edge and had little to no floodplain area. Riparian vegetation within a remnant stand of high-graded old growth along upper Webster Creek is consistent with this description, as there is only a narrow streamside band of shrubs and red alder within a matrix of coniferous forest.

Notes from the General Land Office (GLO) surveys conducted in the 1880s and 1890s before extensive timber harvest took place support this view of pre-settlement conditions along steeper streams in the Lower Watershed. The GLO notes typically describe the vegetation along a section line as, "Heavy fir (i.e., Douglas fir), hemlock, cedar, and spruce timber. Dense undergrowth of the same with vine maple, devil club, and heavy fallen timber." Witness trees at section corners and half sections were also of these same species, although there were occasional alder or maple witness trees. Most of the riparian areas would not be expected to be markedly different from these upland areas, but the immediate streamside zone and channels disturbed recently by a debris flow likely had some hardwoods and more abundant shrub vegetation.

The upper reaches of these streams grade into unconfined alluvial channels on glaciofluvial terraces that are well above the present valley floor. Although there are extensive wetlands in these areas, the limited GLO notes that describe wetland and riparian areas indicate that conifers are the dominant trees, similar to the steeper slopes. Although there is opportunity for streams, such as lower Rock and Webster creeks and upper Williams Creek to migrate and avulse, their small size limits their disturbance capability. However, some gaps in the conifer overstory were probably generated by channel movement, windthrow, and beaver activity. We speculate that there were patches of dense hardwood shrubs and trees within these gaps.

Similar to the Cedar River, the lower portions of Taylor Creek (including the lower North, Middle, and South forks) also flow through glaciofluvial deposits, which were formed when the Green River flowed through this valley during the Pleistocene (Foster Wheeler 1995). Although the lower elevations of Taylor Creek and its various forks are incised into these glaciofluvial deposits, there are moderately confined reaches with substantial floodplain and channel migration zones, where fluvial disturbance plays a strong role in structuring riparian communities. Historically, there was likely a heterogeneous floodplain topography and a complex mosaic of riparian communities in these reaches, including some hardwood dominated areas. The lower order streams in the upper portions of the Taylor Creek subbasins originate in steep mountainous terrain that was not directly affected by glacial erosion or deposits (Foster Wheeler 1995). Riparian areas along these steeper headwater tributaries were probably similar to the low order reaches of Webster, Williams, Rock and Steele creeks, although the frequency of disturbance from debris flows may have been higher in the North and South forks due to high instability of some ancient, deep-seated landslides and inner gorges.

Upper Watershed Streams

The topography and geology of the Upper Watershed is strikingly different than that of the Lower Watershed, and these differences strongly affect stream and riparian characteristics. The upper Cedar and Rex river valleys were carved by alpine glaciers, although there are also deposits of continental glaciers in the western portion of the basin around Chester Morse Lake. U-shaped valleys with steep walls, moraines, and cirque basins are some of the prominent geomorphic features in the Upper Watershed that are the result of this glacial history.

Chester Morse Lake (previously known as Cedar Lake, which is now higher due to the construction of the Masonry Dam and the Overflow Dike) was formed by delta moraine deposits from meltwaters of the vast Puget Lobe glacier that blocked the outlet of the valley from about 23,000 to 14,000 years ago (Hirsch 1975). The lower reaches of the upper Cedar and Rex rivers flow across deltas into the lake. Upstream of the deltas, the valleys of these rivers are approximately 0.5 miles wide forming wide channel migration zones and floodplains. These unconfined alluvial reaches extend for approximately 2.5 and 1.6 miles up the Cedar and Rex rivers, respectively. Moderately confined alluvial reaches extend up the Cedar River to Bear Creek.

Remnant stumps and historical reports (Plummer 1902) indicate that riparian areas along the delta and lower alluvial channels of the Rex and Cedar rivers supported highly productive coniferous forests of large western redcedar, Douglas fir, Sitka spruce, and western hemlock. Fluvial disturbance was likely very active in these reaches. From a 1930 aerial photograph taken shortly after the valley bottom was logged upstream to near Findley Creek, remnant stands of unlogged hardwoods are evident among the anastomosing channels of the Cedar River below Roaring Creek. Hardwood and mixed hardwood-conifer riparian communities are also evident in the narrower floodplain within the reach between Findley and Bear creeks.

Historically, wood jams would have played an important role in channel migration, avulsion, and forest development in these reaches. The unconfined, alluvial reaches of the Cedar and Rex rivers were, and still are, the most dynamic streams in the CRW, and their riparian communities were structured by a high frequency and magnitude of fluvial disturbance.

Above the alluvial valley bottoms of the of the Cedar and Rex rivers and Boulder Creek, riparian areas generally border confined, alluvial channels with narrow floodplains and channel migration zones. However, a few lower gradient, less confined reaches occur along the upper North and South forks of the Cedar River. Using riparian areas in remaining stands of old growth in the Upper Watershed as a reference for pre-harvest conditions, vegetation in confined valleys of the Cedar and Rex rivers was characterized by old growth conifers to near the stream edge, with narrow zones of distinctive riparian vegetation. Disturbance along these reaches was primarily from infrequent debris flows originating from steep tributaries and led to scattered strips of early successional hardwood shrubs and trees. Historic frequency of debris flows in the watershed have not been quantified.

Wetlands and Lakeshores

Upper Watershed

Non-riverine riparian areas in the CRW include lakeshores and several large wetland complexes. Cedar (Chester Morse) Lake was historically the largest lake in the watershed. The construction of the Masonry Dam and Overflow Dike raised the lake level elevation from 1,532 feet to 1,563+ feet, inundating previous lacustrine wetland areas and creating new wetlands along the new shoreline. Historical aerial and oblique photographs of the lake from the 1920s and 1930s show a lakeshore that has been stripped of nearly all vegetation by logging operations. This suggests that the shoreline was mostly conifer forest, although some hardwood trees and shrubs may have been removed during slash clearing operations. Historically, lower gradient lakeshore near the lower end of the lake likely supported some hardwoods, as it does currently. Historical maps show wetland complexes in the deltas of the Cedar and Rex rivers. The artificial lake/reservoir level fluctuations have radically altered the historic hydrogeomorphic dynamics of these river deltas. The delta aquatic and riparian ecosystem composition, structure and functions have no doubt changed in response this perturbation. Delta vegetation currently present is a mosaic of sedge (*Carex* spp.), willow shrub, and hardwood, and conifer forests. Pre-settlement delta ecosystems may not have included all the current plant communities or they may have been in different proportions. Examination of GLO notes and maps may help to resolve these questions.

Other lakes and ponds in the Upper Watershed include Findley, Bear, Twilight, Sutton, Mosquito, and Abiel lakes and Rex Pond. These are all in cirque basins above 3,000 feet elevation, and all but Rex Pond and Twilight and Sutton lakes are still surrounded by old-growth forest. Pre-settlement wetland vegetation around these higher elevation waters bodies was probably very similar to present conditions, which is typically conifer forest (silver fir [*Abies amabilis*], western hemlock, and mountain hemlock [*Tsuga mertensiana*]) with shrub understory (e.g., *Vaccinium* spp.) on steeper shorelines and shrub communities (willow, hardhack [*Spiraea douglasii*]) and meadows of variable species composition on low gradient shorelines. Wetland meadow vegetation includes sedges, rushes (*Juncus* spp.), and a variety of forbs and grasses.

There are two large bog complexes in the Upper Watershed at the base of Little Mountain. These bogs form the headwaters of Eagle Ridge and Morse creeks. Logging has occurred around them, but they were largely left intact following timber harvest. Although timber harvest may have altered the adjacent bog vegetation to some degree, existing vegetation includes plant communities dominated by Labrador tea (*Ledum groenlandicum*), sweet gale (*Myrica gale*), hardhack, sedges, and grasses.

Lower Watershed

Walsh Lake is the only lake in the Lower Watershed. Timber harvest and some clearing of homesteads has occurred around its shoreline. GLO notes of a meander survey around the lake indicate that there was “marsh” as well as “timber and undergrowth” near its shore. Currently, there are extensive areas of cattail (*Typha latifolia*) marsh and numerous areas of dense shrub (willow, red-osier dogwood). It is likely that these species were also common along the lakeshore prior to settlement.

There are complexes of beaver dams and ponds associated with Rock and Williams creeks. Although these riparian areas are found along streams, the extent and the characteristics of beaver-created wetland complexes makes them quite different than other riverine riparian zones. Within these wetland complexes there is a mosaic of plant communities that are the result of variations in topography and hydrologic regime resulting from the history of beaver dam construction and abandonment. Communities now present include open areas dominated by grasses and sedges, willow thickets, alder/salmonberry, and coniferous forest. GLO notes from 1891 in the vicinity of the Rock Creek wetlands indicate that there were clearings in the same areas where they occur now, suggesting that they may be more than 100 years old and thus representative of pre-settlement conditions. Timber harvest and historical fire may have played a role in the conversion of coniferous forest to hardwood dominated communities in these areas; GLO notes suggest that there were more conifers than currently present. Given the uniqueness of these wetland complexes in the watershed, it would be valuable to better understand their pre-settlement character as a basis for developing a restoration reference model.

Other wetlands in the Lower Watershed include a small unnamed bog near the junction of the 16 and 40 roads (T22N, R7E, boundary of Sections 15 and 16), and the Fourteen Lakes. These are all kettle ponds, which are depressions left in the land by large chunks of remnant ice following retreat of glaciers. The small unnamed bog appears largely intact, although the forest around it was harvested early in the 20th century. It has characteristic bog species such as Labrador tea, bog laurel (*Kalmia microphylla* ssp. *occidentalis*), and bog cranberry (*Oxycoccus oxycoccus*). Fourteen Lakes is a group of ponds that fluctuate in depth and extent seasonally. Second growth coniferous forest extends down to their upper shore, indicating they were likely disturbed by logging, but the degree to which they have been altered by this disturbance is not known.

Anthropogenic Effects on Riparian Conditions in CRW

History and Nature of Human Impacts

Impacts to riparian areas in the CRW from humans prior to settlement by Euroamericans were likely minimal. Settlement in the Watershed began as early as 1858, but extensive timber harvest did not begin until after 1900. Timber harvest generally progressed from the western portion of the Watershed east to higher elevations during the early 1900s, and by 1930 the forests around Chester Morse Lake and up the Cedar River to Roaring Creek were clearcut. Clearcutting of the higher slopes in the Upper Watershed continued until the 1990s. Early logging used railroads to remove logs, but by the 1940s the logging railroads were replaced by haul roads allowing removal of logs by truck. During the course of the CRW's logging history and its use for water and power supply, over 600 miles of road were constructed. There has also been removal of large woody debris from some stream reaches.

The harvest of timber and construction of roads had a variety of direct and indirect effects on riparian areas. Direct effects included the removal of riparian coniferous forest and their replacement by early successional plant communities dominated by deciduous species. One of the most important indirect effects of timber harvest and road building on riparian areas has been the increase in debris flow frequency on steeper slopes (Foster Wheeler 1995). As described above, debris flows result in the removal of riparian vegetation, scouring of stream channels and the input of sediment and large wood to the stream.

Construction of the Masonry Dam in 1916 resulted in flow regulation of the Cedar River and an increase in the lake level of historic Cedar Lake. In addition, annual fluctuation in lake level increased from probably a few feet to over 30 feet.

Ecological Consequences of Human Impacts

Although a thorough characterization of the CRW has yet to be completed, we can make some reasonable hypotheses about how land-use activities of Euroamericans from the late 19th century to the present have impacted CRW riparian areas. A more complete assessment of the ecological effects of human impacts in the CRW, however, may alter some of these hypotheses.

Wide-scale harvest of riparian forests in the watershed has resulted in a shift from mature riparian forest vegetation to the current prevalence of early to mid-successional stages. These early to mid-successional riparian forests are characterized by smaller trees, less heterogeneous forest structure, and a greater proportion of hardwood-dominated riparian communities. Strong competition from hardwoods and shrubs has probably resulted in a low rate of conifer establishment and growth in many riparian areas. Conifer regeneration may also be reduced due to less coarse woody debris substrate (i.e., fewer nursery logs) and low conifer seed availability where recent, extensive harvest has eliminated seed sources.

This alteration of riparian areas has, in turn, affected aquatic habitats by:

- reducing the rate of large wood recruitment and associated habitat forming processes,
- removing shade, thereby increasing stream temperature and primary productivity,
- changing the nature and quantity of litter input, and
- reducing root strength along stream banks.

These effects are to be addressed in detail in the strategic plan for aquatic restoration in the CRW.

Debris flows from steep slopes and channels have resulted in the removal of riparian forest adjacent to channels in headwater colluvial and confined process domains and affected riparian and aquatic areas downstream, where sediment was deposited and further mobilized by the stream. Recent channel braiding, possibly resulting from increased sediment input, has caused widespread fluvial disturbance of riparian areas along the Cedar River above Chester Morse Lake. A similar pattern of human-induced impacts may also have occurred in Taylor Creek.

In contrast to a greater level of disturbance in recently braided reaches, removal of large wood from streams and the loss of large wood recruitment has reduced the rate of channel migration or avulsion within the channel migration zone of most low gradient CRW streams. Reduced channel movement has caused reduced levels of floodplain disturbance, resulting in creation of less riparian and aquatic habitat heterogeneity. In the lower Cedar River below Cedar Falls, a lower magnitude and frequency of flooding due to flow regulation, as well as the removal of in-channel large woody debris, has contributed to reduced levels of riparian and aquatic habitat forming processes. However, the narrow floodplain and channel migration zone along this portion of the river provides relatively little opportunity for riparian habitat complexity, even under a natural disturbance regime.

Increase in lake level and lake level fluctuation has had a major impact on riparian areas along the Cedar and Rex river deltas. Remnant stumps indicate that there were riparian forests of very large trees on these deltas that are now permanently or seasonally flooded and occupied by lake bottom, sedges, or hardwood shrubs and trees. These ecological effects on the Cedar and Rex river deltas are expected to persist as long as the lake is regulated for water and power supply.

Preliminary Assessment of Existing Conditions and Processes in CRW

As described above, timber harvest, road building, and regulation of stream flow and lake level have had a wide range of ecological effects in riparian areas. These altered conditions lead us to ask: To what degree and extent are riparian areas in the watershed failing to provide the ecological functions and services needed for sustaining a self-regulating natural ecosystem?

Because an extensive characterization of riparian areas has not been conducted, we presently lack information needed to answer this question. Based on non-systematic observations of riparian areas in the watershed, we can, however, make a preliminary assessment of riparian conditions. Potential "problems" in riparian areas that have major impacts on aquatic habitat include: (1) lack of large conifer trees that contribute to inchannel large wood recruitment and shade, (2) bank instability due to reduced root strength or disruption of natural stream flow-sediment processes, and (3) hillslope instability induced by timber harvest and road construction. In addition to these impacts to aquatic areas, there may be reduced ecological functions of CRW riparian areas pertaining to wildlife habitat and large-scale landscape complexity.

Reduced Size and Proportion of Coniferous Trees in Riparian Areas

Most of the riparian areas in the CRW lack the size of coniferous trees that were present at the end of the 19th century. In much of the Lower Watershed and the lower valley bottoms of the Upper Watershed, conifers in second-growth riparian forest are at or approaching a diameter that can function as pool-forming large wood (> 20 inches) and are beginning to be recruited to streams. In many of the more recently harvested areas of the Upper Watershed, young, high density conifer stands dominate riparian areas. Abundant hardwood dominated riparian areas are found in the Rock, Williams, and Taylor creek subbasins, with more restricted distribution in the lower Cedar and Rex river basins. From general observations, most of the hardwood dominated riparian areas in the CRW appear to occur along low gradient streams. Although floodplains are typically dominated by hardwoods due to frequent, repeated disturbance, many terraces with poorly drained soils in the CRW continue to be dominated by hardwoods > 70 years after timber harvest. The extent of both young, dense conifer stands and hardwood dominated riparian forests in the CRW has not been mapped at this time. Such information will be necessary to prioritize riparian and aquatic areas in the CRW that would benefit from silvicultural intervention.

Bank Instability

Root strength provided by bank vegetation would be expected to increase relatively quickly with succession following disturbance. Herbaceous plants, shrubs, hardwoods, and young conifers all contribute to root strength, and in the relatively moist climate occurring in the CRW, revegetation occurs relatively quickly following disturbance. Since the amount of commercial timber harvest in the past ten years in the watershed has been minimal and is no longer occurring under the HCP, current vegetation of most CRW riparian areas should be sufficient to provide necessary root strength for stabilizing stream banks.

There may be areas of persistent bank instability, however, along reaches with unconsolidated bank materials that are highly susceptible to erosion and where channel braiding is continuing due to increased sediment loads. Taylor Creek flows through areas of unconsolidated glacial outwash and is reported to have reaches with persistent bank instability. Chronic turbidity in Taylor Creek during high flow events is evidence for the presence of bank instability. Whether or not the present level of bank erosion is higher than pre-harvest rates is not known. Channel braiding in the upper Cedar River below Roaring Creek is ongoing and the frequent disturbance caused by shifting channels continually removes young riparian vegetation and results in unstable banks. These processes are inherent in riparian areas along braided streams. Channel braiding and unstable banks of unconsolidated alluvium in this reach of the upper Cedar River can be expected to continue as long as sediment and flow conditions are conducive to channel braiding.

Hillslope Instability and Mass Wasting Induced by Timber Harvest and Road Construction

The CRW has a wide range of unstable hillslope conditions, many of which have been aggravated by historic timber harvest and road construction. Hillslope stability issues of concern relative to the restoration of riparian and aquatic ecological processes in the CRW are twofold. First, historic timber harvest and road construction practices have resulted in significant increases in mass wasting and debris flows on steep, unstable hillslopes. This has resulted in an increase in the frequency and magnitude of coarse and fine sediment delivery to a range of channel types in all process domains. Second, the ecological impacts of these increases on riparian ecosystems can be significant and include the direct effects of scouring and deposition on existing vegetation, persistent instability of inner gorge walls, and secondary effects of increased sediment loads on channel form and bank stability. Because no assessments of the hillslope instability and mass wasting impacts to riparian areas have been made, we do not know the extent or the present condition of CRW riparian areas so affected. Inner gorge walls in the headwaters of the North and Middle forks of Taylor Creek are known to have continued instability problems, whereas most alluvial fans likely have become revegetated and support early to mid-successional plant communities. Detailed mapping of vegetation using high resolution remotely sensed imagery will be of major value in assessing the present condition of riparian areas affected by mass wasting and hillslope instability.

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Cedar River Watershed
Riparian Restoration Strategic Plan

Appendix B
Benchmarking: Riparian Restoration in the Pacific Coastal Ecoregion

Benchmarking for Effectiveness Monitoring of Riparian Treatments

Existing monitoring plans and methodologies related to riparian effectiveness monitoring include RRMC (2003), WFPB (1997), Smith and Schuett-Hames (1998) and Beech (2003). The Timber/Fish/Wildlife (TFW) Effectiveness Monitoring and Evaluation Program has the most applicability to riparian project specific monitoring in the CRMW, as it has a detailed methodology that is being implemented, is driven by explicit monitoring questions, and is at a spatial scale most comparable to the CRMW circumstances (Smith and Schuett-Hames 1998). The riparian component of the TFW Effectiveness Monitoring and Evaluation Program is primarily oriented towards evaluating effectiveness of management and restoration actions on LWD recruitment and shade. Methods ultimately selected for riparian monitoring in the CRMW may not exactly conform to the TFW methods due to our specific needs, interest, and available monitoring resources, but they should serve as a good model.

Sampling frequency recommended by TFW (Smith and Schuett-Hames 1998) is before treatment, immediately after treatment, at intervals of one to five years for the first ten years, and every five years thereafter. This schedule may need to be modified depending on available monitoring resources and specific monitoring questions. Although established plots with baseline information can almost always provide useful information if resampled years later, it is not cost effective to establish more monitoring projects than can be reasonably resampled in a timely manner. Number and intensity of monitoring projects need to be scaled to available resources.

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Cedar River Watershed
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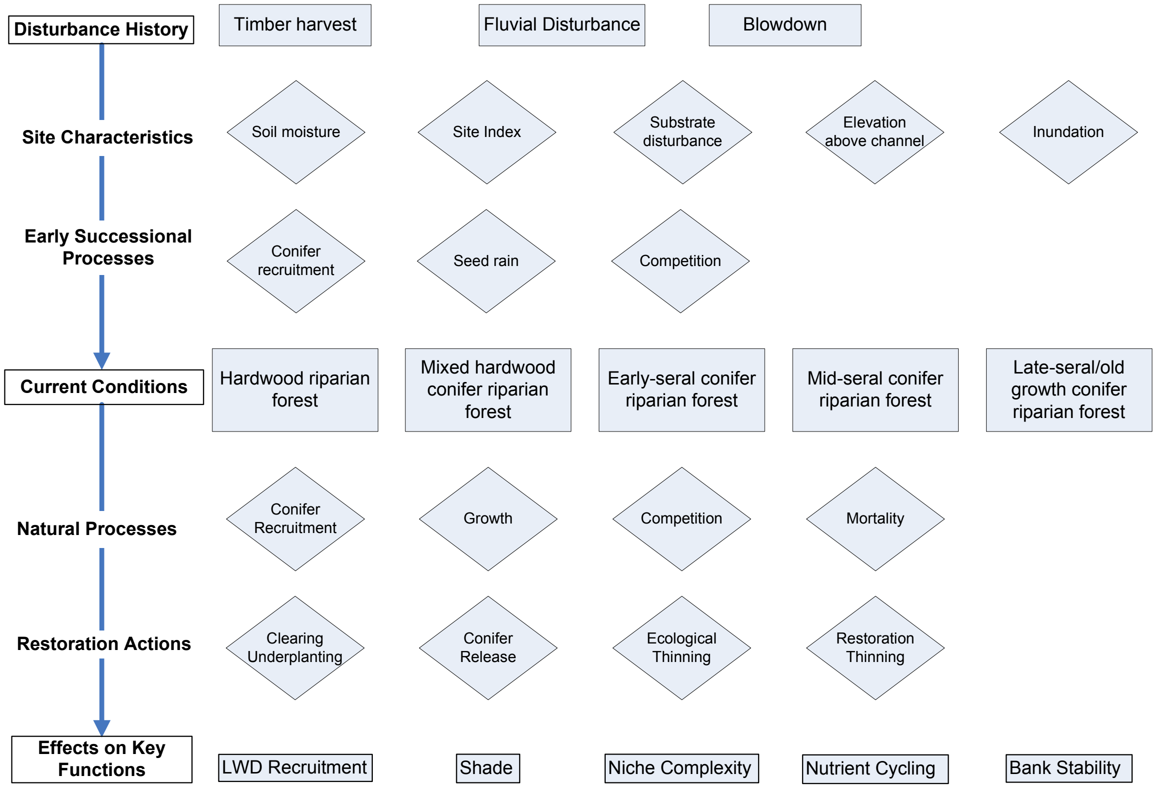
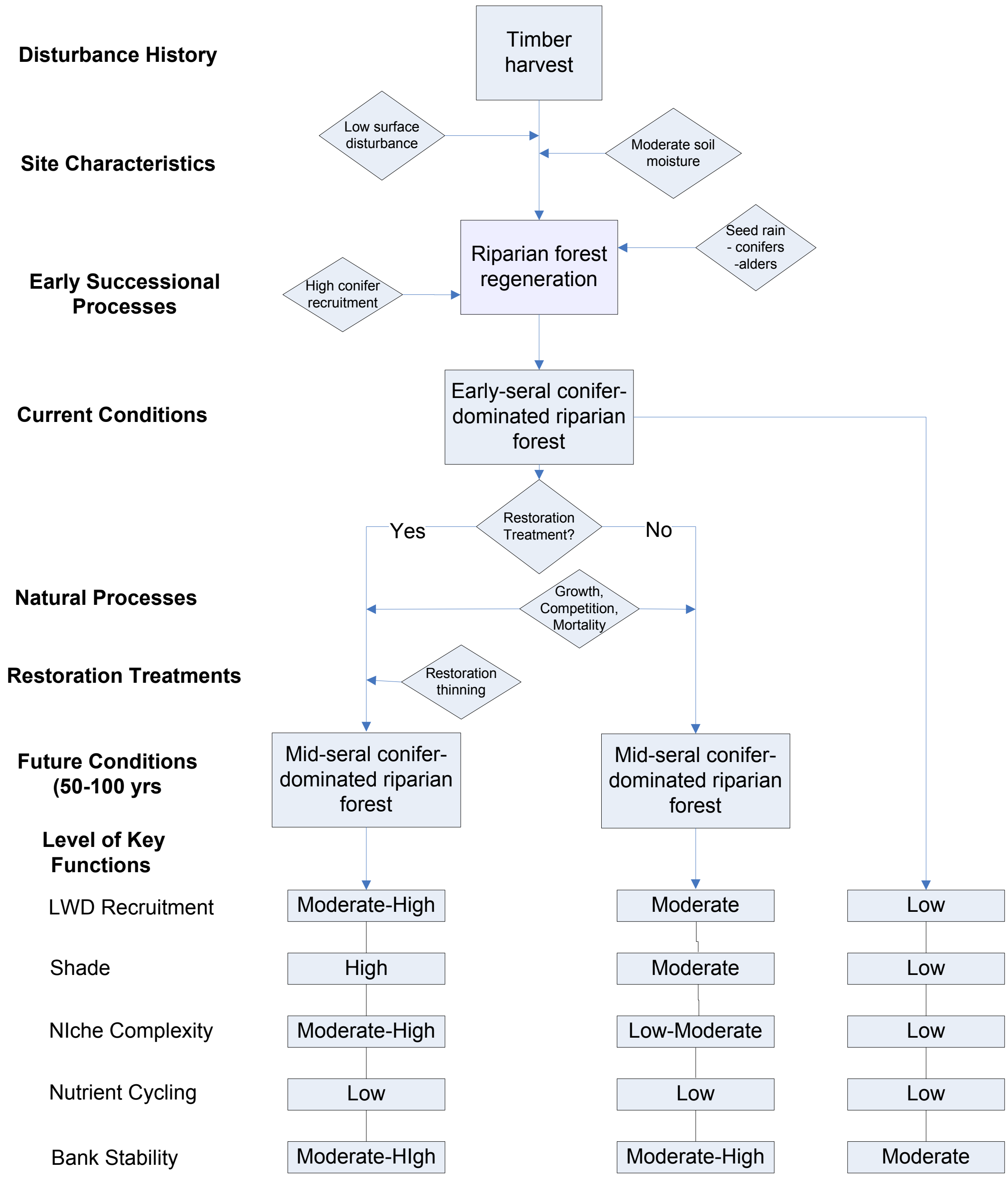
Appendix C
Conceptual Models for Riparian Conservation Targets in the Cedar River Municipal Watershed

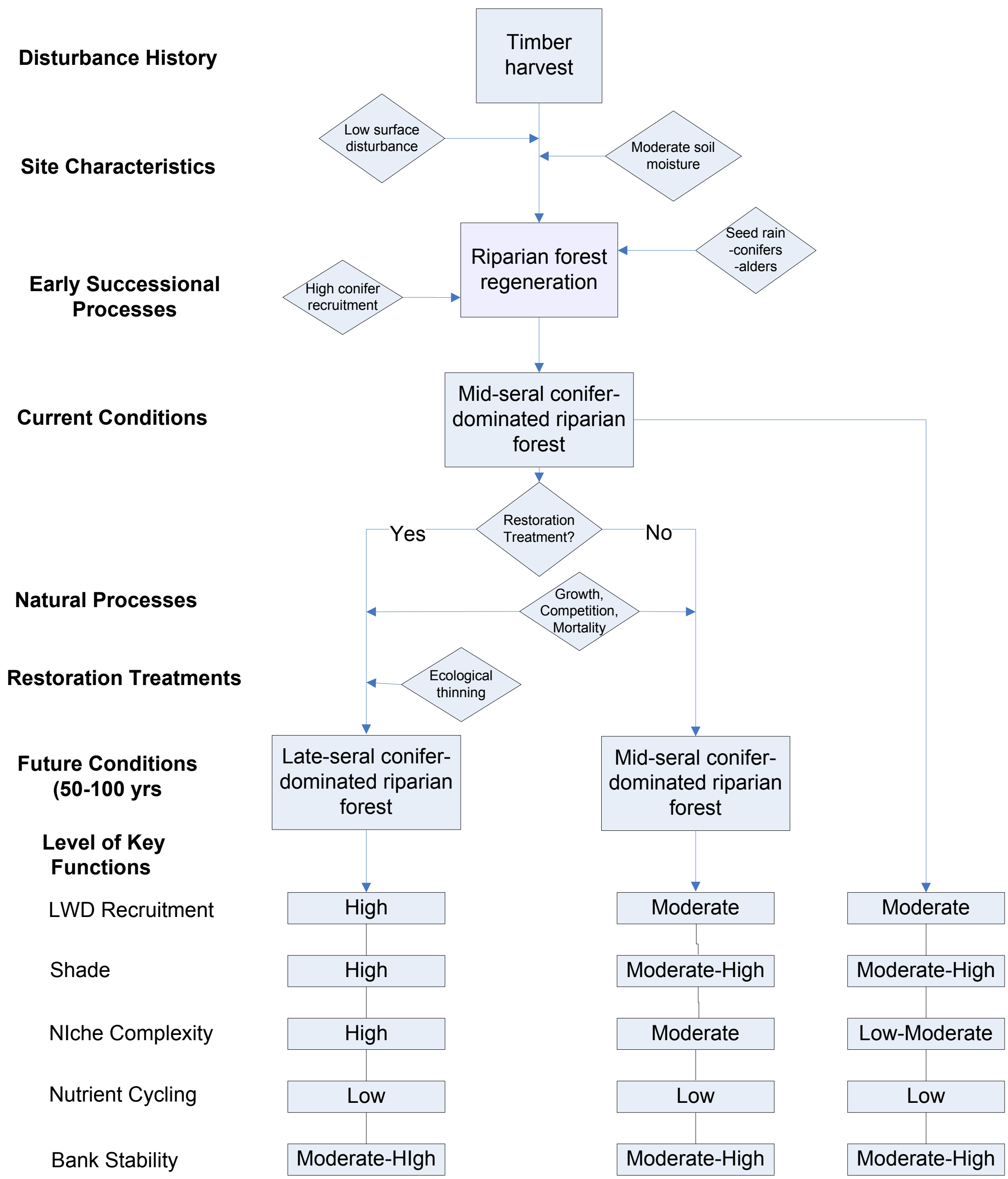
Template for Conceptual Models of Riparian Forest Conservation Targets



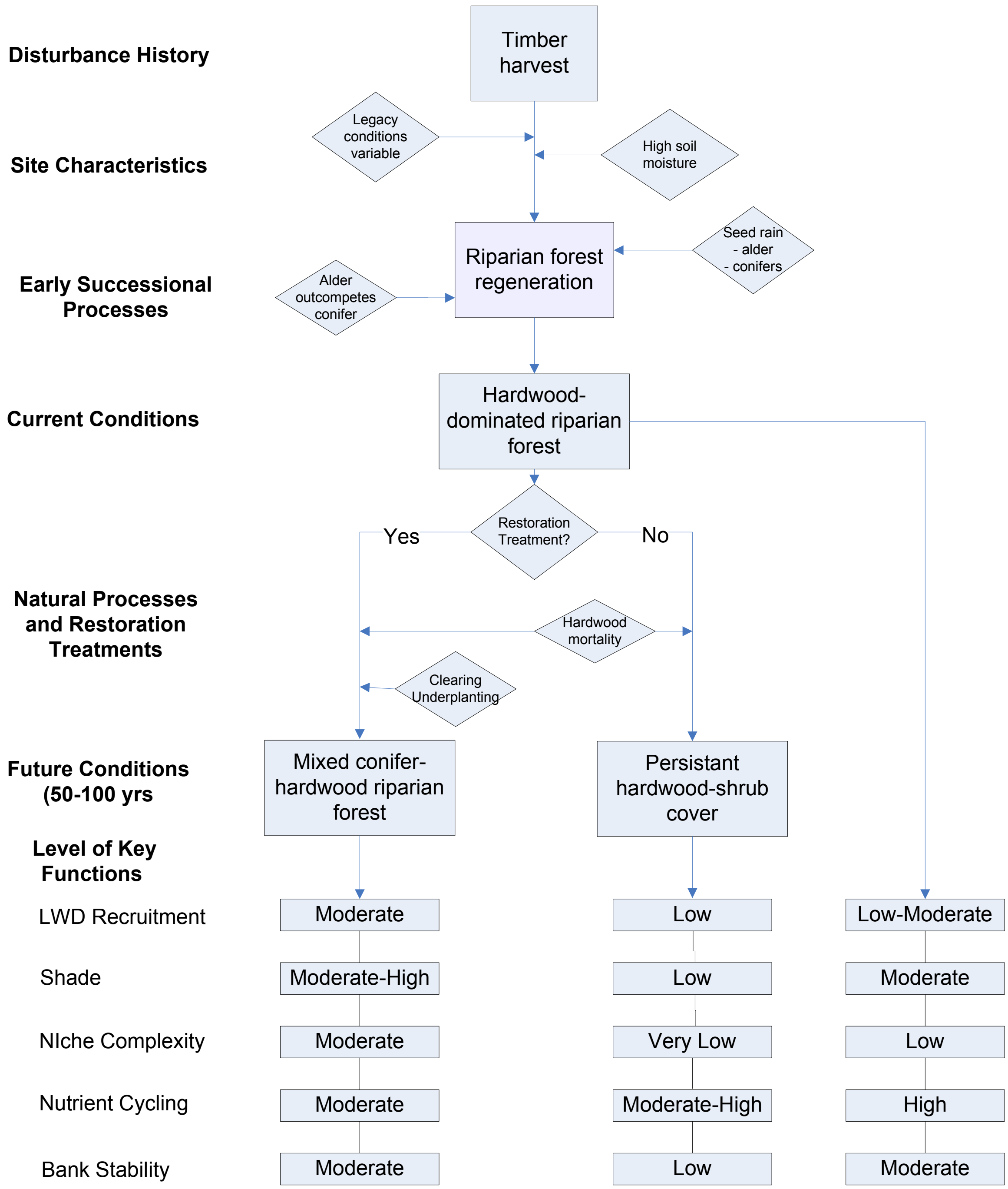
Conceptual Model for Riparian Forest Restoration: Early-seral Conifer / Terrace-Hillslopes and Headwater Streams



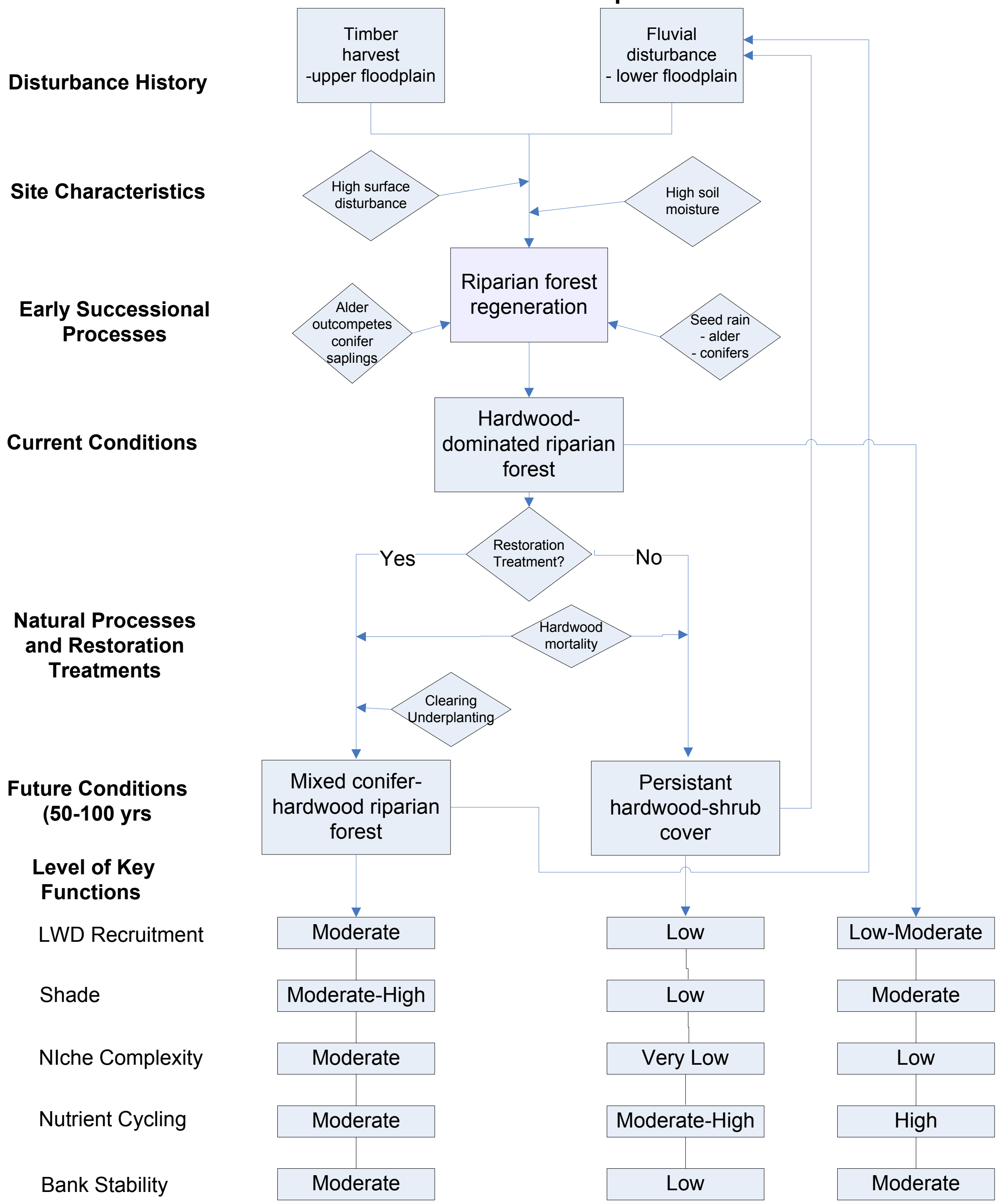
Conceptual Model for Riparian Forest Restoration: Mid-seral Conifer / Terrace-Hillslopes and Headwater Streams



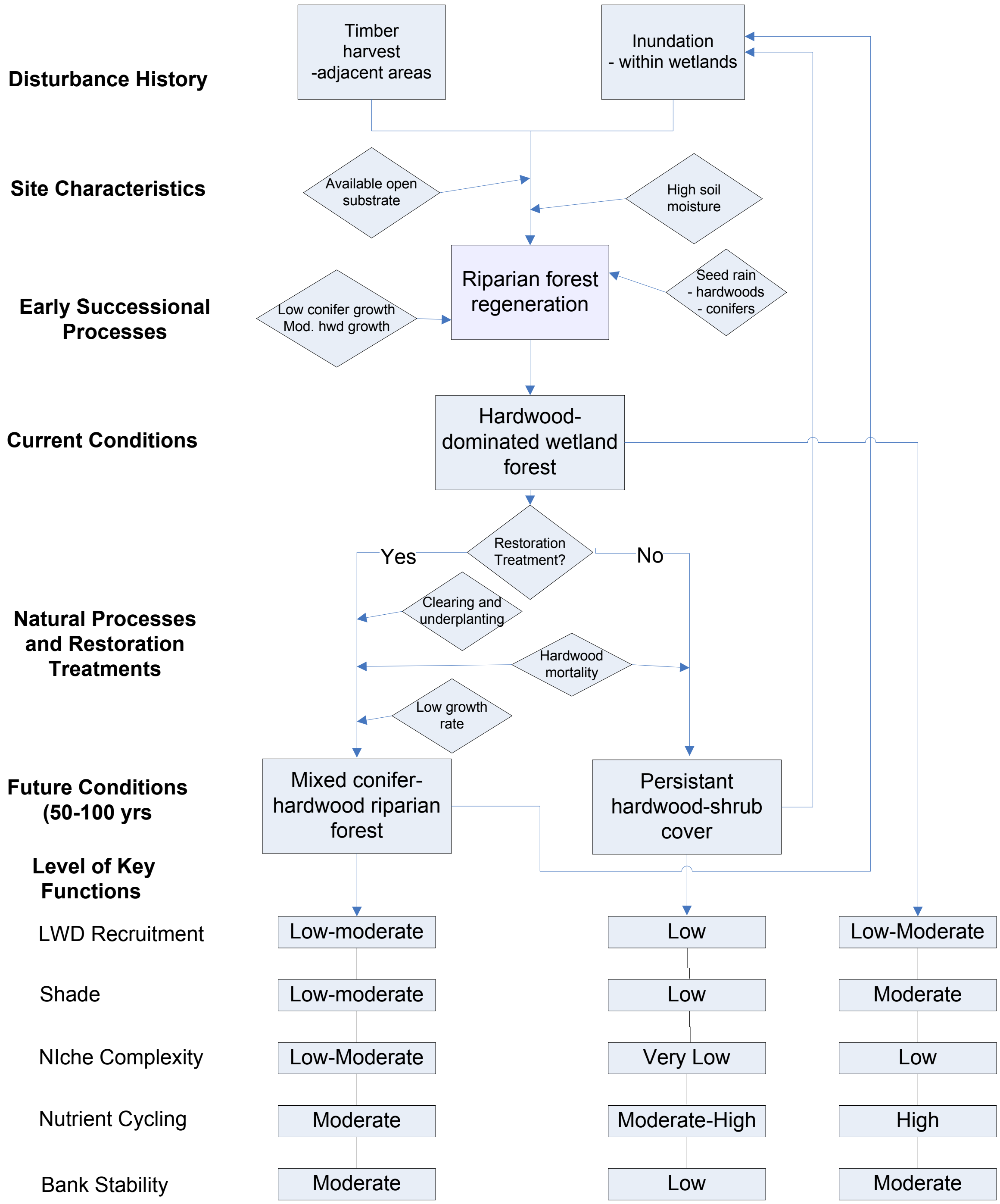
Conceptual Model for Riparian Forest Restoration: Hardwood-Dominated / Terrace-Hillslopes and Headwater Streams



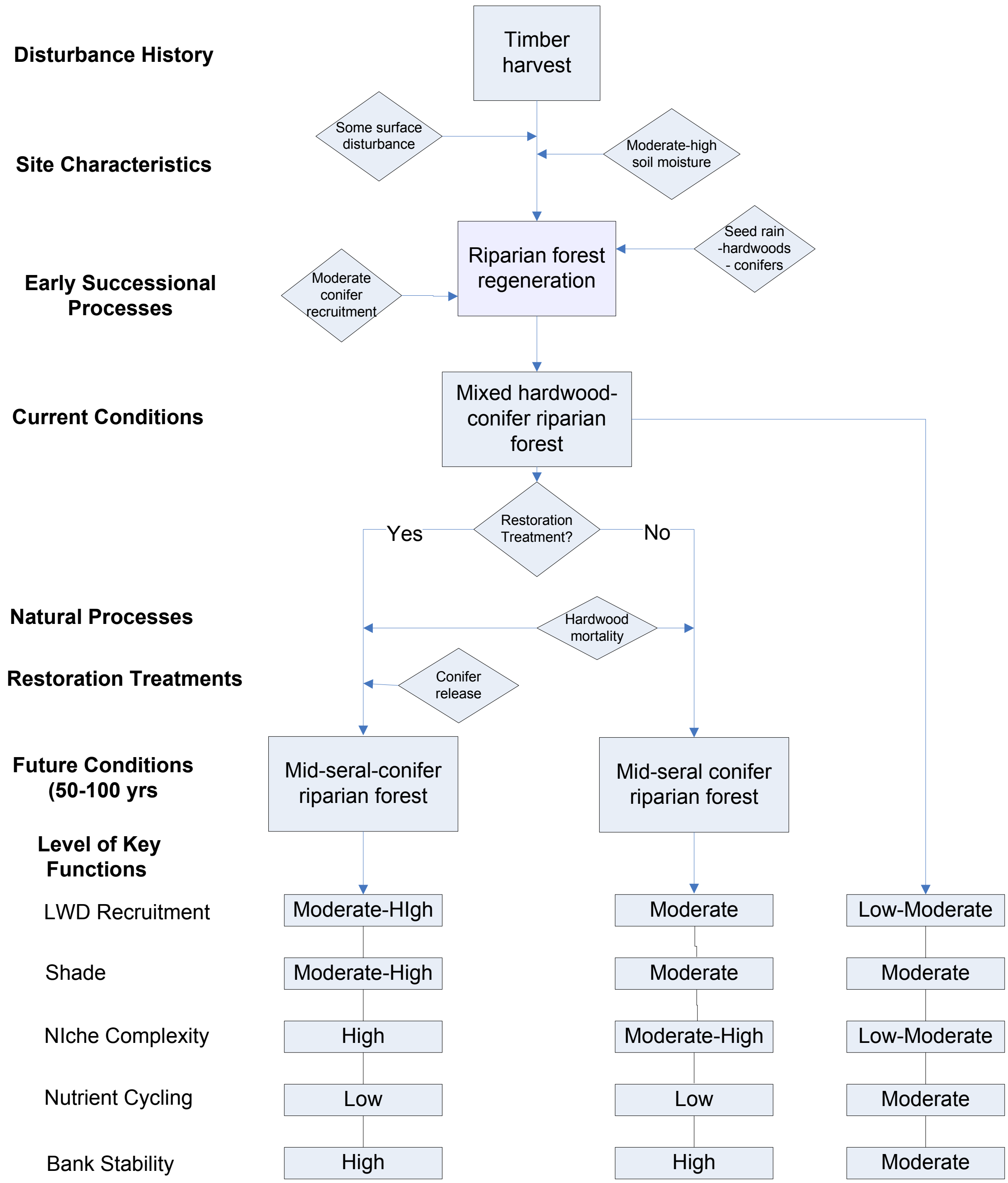
Conceptual Model for Riparian Forest Restoration: Hardwood-Dominated / Floodplains-Alluvial Fans



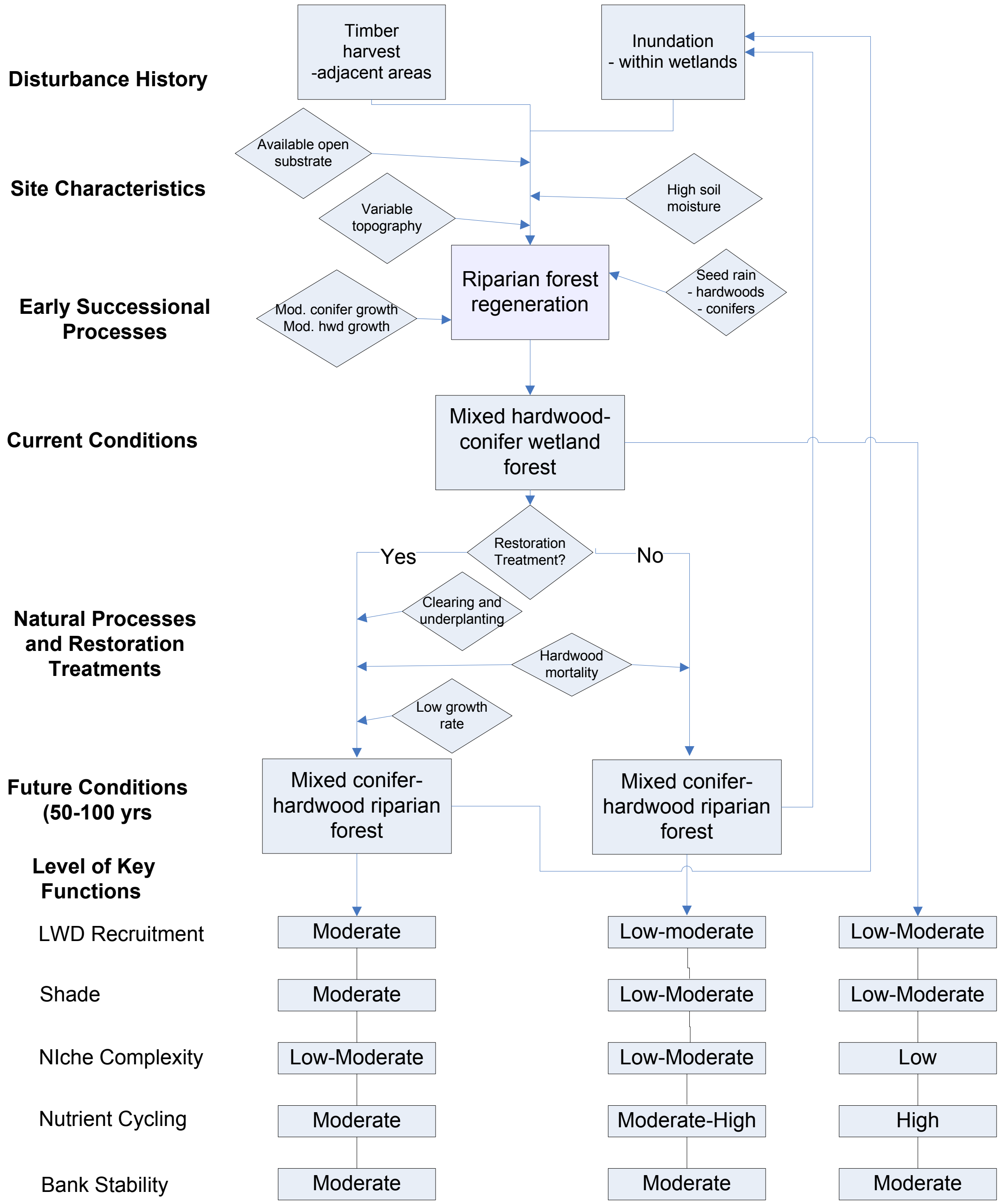
Conceptual Model for Riparian Forest Restoration: Hardwood-Dominated / Wetlands

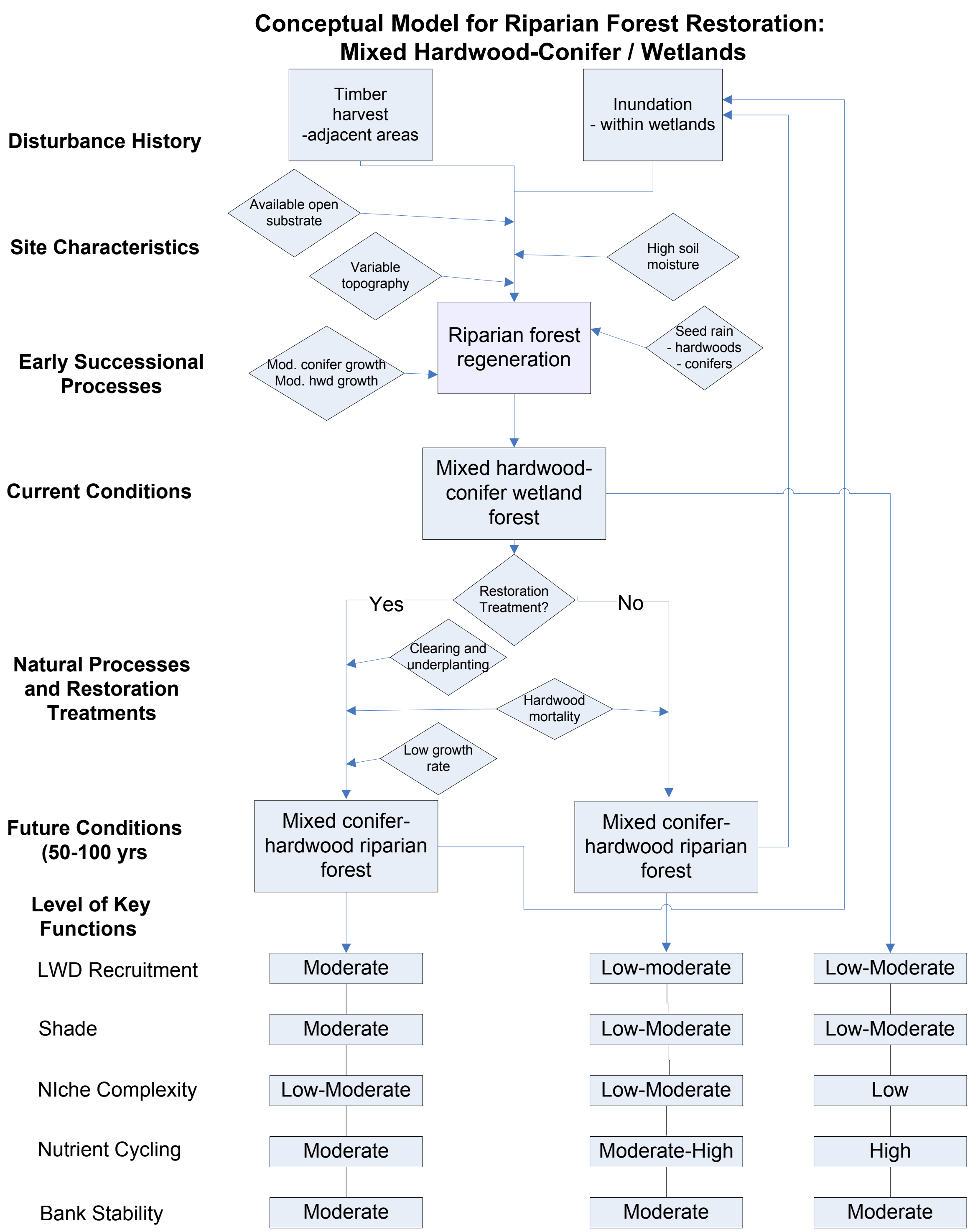


**Conceptual Model for Riparian Forest Restoration:
Mixed Hardwood-Conifer / Terrace-Hillslopes and Headwater Streams**



Conceptual Model for Riparian Forest Restoration: Mixed Hardwood-Conifer / Wetlands





Conceptual Model for Riparian Forest Restoration:
Mixed Hardwood-Conifer / Wetlands
Disturbance History
Timber harvest -adjacent areas
Inundation - within wetlands
Site Characteristics
Available open substrate
Variable topography
High soil moisture
Early Successional Processes
Mod. conifer growth Mod. hwd growth
Riparian forest regeneration
Seed rain - hardwoods - conifers
Current Conditions
Mixed hardwood-conifer wetland forest
Restoration Treatment?
Yes
No
Natural Processes and Restoration Treatments
Clearing and underplanting
Hardwood mortality
Low growth rate
Future Conditions (50-100 yrs
Mixed conifer-hardwood riparian forest
Mixed conifer-hardwood riparian forest
Level of Key Functions
LWD Recruitment
Moderate
Low-moderate
Low-Moderate
Shade
Moderate
Low-Moderate
Low-Moderate
NIche Complexity
Low-Moderate
Low-Moderate
Low
Nutrient Cycling
Moderate
Moderate-High
High
Bank Stability
Moderate
Moderate
Moderate

Cedar River Watershed
Riparian Restoration Strategic Plan

Appendix D
Information Management and Documentation

Establish procedures to ensure appropriate documentation of:

(1) Protocols for data collection and modeling (descriptions of the parameters and associated ranges of values with which models are driven, facilitating more detailed interpretation of model outputs, recording how we created the information)

(2) Acquisitions (how data were actually acquired, with exceptions to protocols, if any, the Data Acquisition Description Document (DADD) concept. We have several examples now plus an annotated template to help authors write these documents quickly. This document captures any departures from a methodology or protocol that were necessary. In addition it is particularly important to document a “get-back-there” description for any field locations that are intended to be re-visited. We borrowed this concept from the BPA surveyors who use it to relocated monumented survey posts. We have developed it for both PSP and PSR DADDs.)

(3) GIS description, including all metadata (Documentation of GIS “layers” that help us to both locate our information and to analyze it. Current versions of ArcGIS facilitate “auto-completion” of many metadata attributes that previously would have been manually entered. We can provide search tools that leverage the metadata directly through the Arc Metadata Server tool.).

Criteria for level of documentation

Identify activities for which documents will be prepared, including final documents and milestone documents for project management (decision needed on this) and:

(1) Project plans
(2) Project as-builts (records of what was actually done, which can be done by showing where deviations from plan occurred and why)
(3) Project monitoring (compliance, effectiveness, and validation (if any))
(4) Trend monitoring reports, especially those based on PSPs (uplands), PSRs (riparian), and formal long-term stream monitoring (aquatic)
(5) Modeling results, such as scenario analyses and other projections, including protocols and assumptions used

The following requirements for documentation will be covered in the Synthesis document:

(1) Annual learning activities (lessons)
(2) Annual planning (1-year, 5-year)
Modifications to strategic plan